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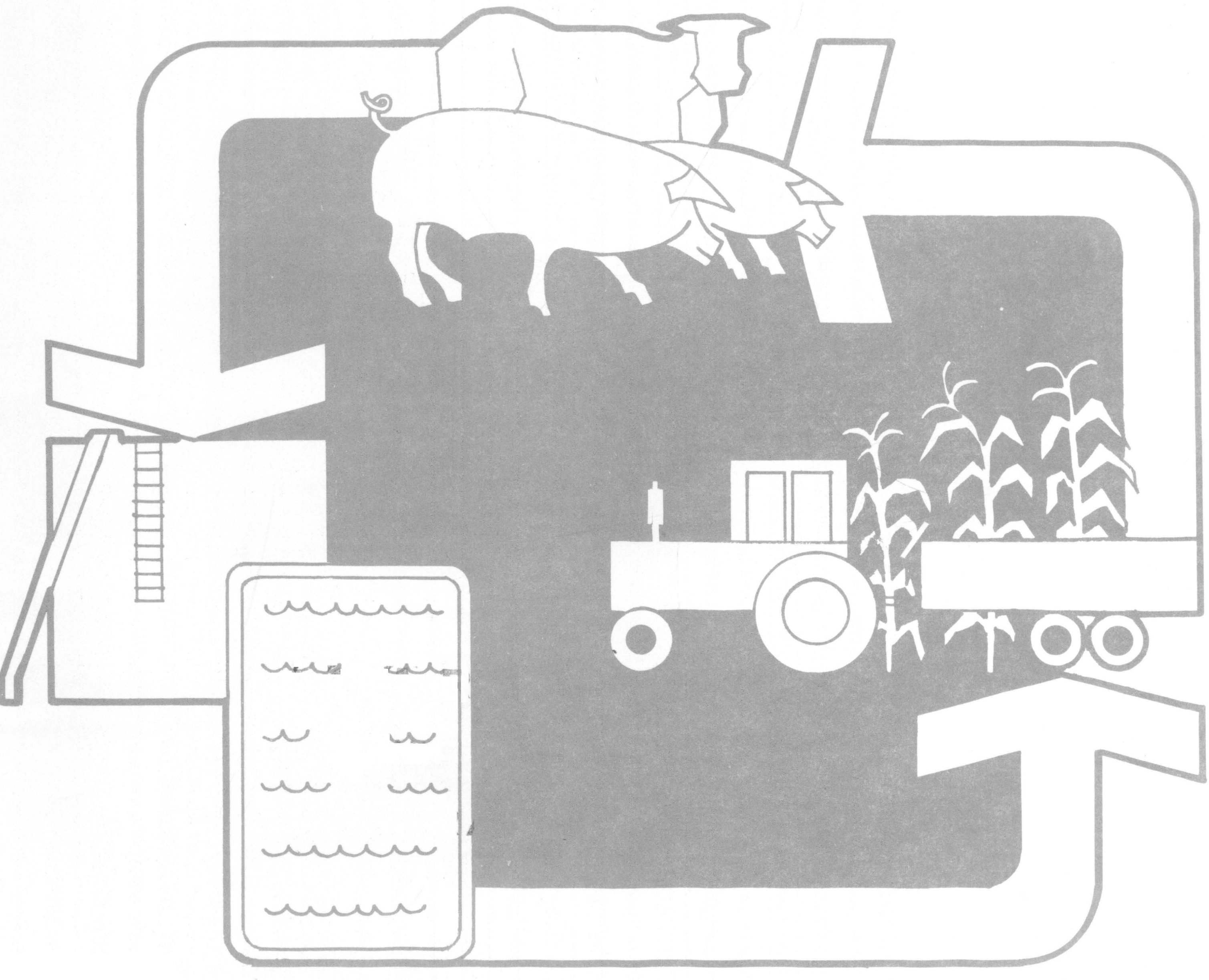
OHIO LIVESTOCK WASTE MANAGEMENT GUIDE



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Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Roy M. Kottman, Director of the Cooperative Extension Service, The Ohio State University.

INTRODUCTION

Animal wastes can become serious pollutants of air, water and land resources. Degraded stream water quality and fish kills resulting from animal manures and feed wastes are reported each year in Ohio. Such pollution can result from the use of improper practices or careless management. Most livestock owners and operators are conscious of the pollution potential of animal wastes and have utilized means to control it. On the other hand, some have abused air, water or land resources at the expense of environmental quality.

This pollution is of public concern. Some streams are overloaded with wastes from livestock facilities, industries, cities, villages and individual homes. Attention has been drawn to livestock waste pollution by (a) publicity on pollution problems, (b) increased public awareness due to suburban encroachment in rural areas and (c) increased emphasis on control of all sources of pollution. The rights of others to clean water and air should be allowed just as a landowner desires clean water and a pleasant environment. New and better techniques and the use of common sense in management will reduce the problems that livestock owners have in controlling pollution.

Management is the key to pollution control when operating animal facilities. Each livestock owner should choose the kind of waste handling system that most nearly matches his resources, including his ability and desire to operate the system.

This guide contains information that will help a livestock owner or operator make decisions in choosing and operating a livestock waste handling system, which controls pollution.

Beyond the concern for pollution control and compliance with state and federal standards, livestock farmers are generally interested in the fertilizer value of animal wastes. Fortunately, using the nutrients in animal wastes for crop production is a practical method of controlling pollution. So, the value of manure as a source of plant nutrients must always be given strong consideration in animal waste management systems.

ANIMAL WASTE POLLUTION ABATEMENT PROGRAM

Legislative action in Ohio, effective January 12, 1979, shifted **some** of the authority for animal waste pollution abatement from the Ohio Environmental Protection Agency (OEPA) to the Department of Natural Resources, Division of Soil and Water Districts. The action virtually eliminated the requirements for farmers to obtain a permit to construct or operate animal feeding operations involving less than 1,000 animal units.[1]

If more than 1,000 animal units are involved or if the animal facility involves a waste management system having a controlled discharge to waters of the state, the owner must apply for and receive plan approval and a permit to install from the OEPA. Storage or treatment facilities must be constructed and operated so that no overflow will occur, except from precipitation in excess of a 25 year, 24 hour storm. It is not expected that entities with less than 1,000 animal units will have direct discharge of waste waters to the waters of the state. However, in the event that they should, these entities are required by OEPA to apply and obtain plan approval, permit to install and an NPDES permit to discharge.

The Chief of the Division of Soil and Water Districts, as required by the new law, adopted rules establishing state standards and procedures for the abatement of water pollution by animal waste. These rules do not apply to air pollution (odors) from animal feeding operations. The standards that became effective on November 1, 1979, will be used to determine if a water pollution problem exists. They can also be used to plan acceptable abatement practices and develop an appropriate management program to prevent or eliminate a water pollution problem.

The Division of Soil and Water Districts, in cooperation with local Soil and Water Conservation Districts and their assisting agencies, will inform owners and operators of animal feeding operations about the state standards. They will offer assistance in determining if a situation is considered a pollution problem, based on the use of or failure to use management practices to abate the degradation of public waters. Technical assistance is available to help owners and operators develop and evaluate alternatives for solving pollution problems and to help install appropriate practices and develop the related management plans to operate facilities without polluting public waters.

Public funds are available for cost-sharing with private owners to solve a water pollution problem from animal waste. In addition to federal funds through the USDA Agricultural Stabilization and Conservation Service, state cost-share funds are available through

[1] Equivalent to 700 dairy cows, 1,000 fed beef, 2,500 fat hogs, 10,000 sheep, 30,000 chickens (liquid manure) or 100,000 chickens (solid manure), 55,000 turkeys or 5,000 ducks.

the Division of Soil and Water Districts and local Soil and Water Conservation Districts. State funds can be used to pay up to 75 percent of the cost of eligible practices to solve a water pollution problem which existed at the time the standards were adopted, November 1, 1979. Facilities constructed, reactivated or expanded after November 1, 1979, will need to control pollution without state cost-sharing.

Enforcement authority for controlling violations of the state standards for animal waste pollution abatement rests with the Chief of the Division of Soil and Water Districts. The Chief will use such authority only when local information, education, technical and applicable financial assistance fails to bring about a solution to an animal waste pollution problem.

Anyone planning to construct new or expanded animal feeding operations should become familiar with the animal waste pollution abatement standards and seek assistance if necessary to clearly understand them. Questions about the animal waste pollution abatement program, including the technical and cost-sharing assistance available, should be directed to the local Soil and Water Conservation District or the Cooperative Extension Service offices.

CONTROLLING ODORS

When planning a new livestock facility or enlarging an existing one, consider the question. What is the odor nuisance potential? Factors directly affecting odor nuisance potential are: (1) site selection — where the buildings and manure handling facilities are located in relation to neighbors, prevailing wind and air drainage, (2) the proper design of the manure handling system components, and (3) proper operation and management of the waste facility.

Odors are the volatile compounds generated during the decomposition of organic matter (manure). The two principal classes of odorous compounds are those containing sulfur, e.g. hydrogen sulfide, and those containing nitrogen in the amine form, e.g. ammonia. The generation of these compounds is affected by the type of livestock and is primarily associated with the level of protein and amount of roughage in a feed ration. For example, poultry and hog wastes produce more offensive odors than cattle. The manure handling system also affects the rate of odor generation and the characteristic smell of the odor. Manure that is collected and field spread daily has less offensive odors than manure that is stored. Also, manure handled as a liquid (slurry) will have a greater potential for odor nuisance than manure handled in a solid form with bedding. Research indicates that the transport of odors is also associated with dust particles or aerosols. Therefore, controlling dust or aerosol emissions will help to control odors.

A crucial aspect of controlling odors is good management. This includes both the proper operation of the manure handling system and the neatness and cleanliness of the total facility. A well-kept, neat facility will receive less negative reaction to the same level of odor than a debris-laden, weed-covered facility. The maintenance of good public relations with neighbors is essential. The farmer must consider how a particular practice, e.g. agitating manure storage or spreading manure on a field, will affect the odor level being carried to a neighbor. He should always choose that option which will give the least odor nuisance.

SOURCES OF ODORS ON THE FARM

There are three primary sources or areas where odors are generated on the farm. These areas are: (1) the buildings, (2) the manure storage or treatment units, and (3) the spreading of manure and associated waste-waters on cropland.

Odors coming from confinement buildings can be a significant source of nuisance. The management of livestock and manure in the building is important. If manure accumulates longer than three to five days, larger amounts of and more offensive odors are released. Manure accumulated on open lots can pose greater odor nuisance during warm, wet weather than if the animals were totally under roof. If animals become dirty with manure, their body heat will promote the rapid release of odors.

The ventilation system of a building is essential for efficient livestock production. If the generation of odors and gases within the building is large, then these odors and gases will be blown out of the building with the ventilation air. If the building environment is particularly dusty, due to feeding finely ground feed, a higher odor level in the exhaust air may be expected.

Manure in solid form can be stored in roofed or unroofed, walled structures. The common types of liquid manure storage structures are: pits beneath slats, open concrete tanks outside the building, covered concrete tanks, above-ground concrete or metal tanks and earthen storage basins. The most common biological treatment system that also provides storage is the anaerobic lagoon. Odors will be generated in all of the above. With proper design and management, odor nuisance can be minimized.

The spreading of manure on cropland or pasture can be the source of an odor nuisance. Rapid volatilization of odorous compounds takes place because the manure is spread in a thin layer. The release of odors usually subsides in one to three days, unless the weather is particularly humid.

CONTROL OF ODORS

Site Selection: Four factors must all be considered to select a livestock facility site where the odor nuisance potential is kept to a minimum. None of these factors is controlling in itself.

These factors are:
- Isolation of the facility site.
- Direction of, and distance to neighbors.
- Prevailing wind direction.
- Air drainage.

Locate new livestock facilities to give the greatest isolation. How far from the nearest neighbor should the livestock facility be in order to avoid odor nuisance? There is no one answer to this question. The distance of 1,000 feet has been used and offers some protection to odor nuisance problems. It is recommended that the distance to nearby housing developments or towns should be greater than to single homes. Air drainage and prevailing wind direction can alter the needed distance.

The direction to neighbors must be considered in relation to prevailing wind directions. In the Western portions of Ohio, the winds are from the SW quadrant about 60 percent of the time. In the more hilly areas of Eastern Ohio, prevailing wind directions are affected by local topography. If the neighboring residence is in the prevailing downwind direction, greater distances to neighbors are needed.

When a neighboring residence is in a down-slope direction, and in particular, when it is in a swale or small valley, odor nuisance potential increases due to air drainage. During calm, summer evenings, air next to the ground surface will be cooled and drift down-slope. If this drifting air passes a livestock facility, it will pick up the odors being released. This odor laden air will flow down the swale or valley and create a nuisance around dwellings in its path. This meteorological condition may continue for several hours during the evening when people normally like to be out-of-doors.

When the land is relatively flat, prevailing wind direction and distance to neighboring residences will affect the decision on where to locate the facility. If sloping land is on the farm, the air drainage factor must also be considered and may outweigh the prevailing wind direction.

Building Design and Manure Collection: The management of manure handling systems and building layout will affect odor generation. Questions that need to be addressed are: Should manure be handled as a liquid or a solid? Should storage be provided in the building or outside? How often should the lot be scraped?

Principles to consider in selecting the collection system are:

1. Accumulated manure on lot surfaces will give off more odor during warm, wet weather than manure in a pit or tank.
2. Daily scraping of manure from lot surfaces will reduce the generation of odors.
3. Manure left in a building longer than three to five days will have more odor than if it is moved to cropland regularly.
4. Moving liquid manure out of a building in three to five days will lower the odor level in the building . . . and the amount exhausted with ventilation air.
5. Flush systems reduce the odors inside a building . . . and the amount exhausted with ventilation air.
6. In the case of poultry, drying manure below the cages to a moisture content below 40 percent with recirculated air will reduce odor problems.
7. Reducing dust levels within a building will lower odor problems.
8. Scrubbing the exhaust ventilation air will reduce odors coming from a building.

Storage Structures: Except when there is reasonable site isolation, manure storage structures should be covered. For swine and poultry, this usually means a concrete lid or a "plastic" cover on the structure. For dairy and beef manure, a floating crust usually forms, which acts as a "lid."

A floating crust may not form under two conditions: excess water and a low pH. Divert all surface runoff away from the manure storage structure. When a crust doesn't form, check the pH. If the stored waste is below 6.5, add lye (NaOH) or hydrated lime ($Ca(OH)_2$) at a rate of one pound per 1,000 cubic feet daily until the pH rises to 6.7 or above. The lye or lime should be spread over the entire surface or mixed into the wastes. Some producers have blown chopped straw on the waste surface, which has helped to initiate a crust. Storage units initially loaded in the fall or winter will take longer to develop a crust than those started in the spring or summer.

Lagoons: There are two principal types of livestock waste treatment lagoons: aerobic (aerated) and anaerobic (without air). An aerated lagoon properly designed and operated will not produce odors. However, if aerators malfunction or loading exceeds the design capacity, odors may become a problem.

Anaerobic lagoons have been sources of odor nuisance because of improper design and poor management (principally overloading). A well-functioning anaerobic lagoon will have a relatively constant level of suspended solids and dissolved minerals. Little or no odor will be detectable, except during a short warm-up period in the spring. Lagoon design criteria, start-up procedures and management factors are given in the section on Treatment Units. These guidelines are essential for an odor nuisance-free lagoon. In odorous situations, a last resort practice due to high energy costs is to mechanically aerate the surface layer of the anaerobic lagoon.

Spreading Manure: The correct decision of when to spread manure and which field to spread it on will eliminate odor nuisance in most cases of field spreading. To have flexibility in when to spread, manure storage is needed. The decision on which field to use must consider wind direction and speed and distance to neighbors. Also, the method of field application can affect odor release.

Factors to consider in selecting when to spread are:

1. Manure spread in cold weather will create less nuisance than if spread in warm weather.
2. If manure must be spread on warm days, do it in the morning. Air near the ground will be warmed and will rise. The odors will also rise and not travel along the ground surface. Also, the manure will dry more quickly and odor release will taper off sooner, frequently before evening.
3. When there is a wind blowing, the odors will travel a shorter distance before being well mixed in the atmosphere to a point where no odor is detectable.
4. Do not spread on calm, humid days unless the field is isolated.

The principal guideline on where to spread is: do not use fields a short distance upwind from neighbors. Plan to have several fields available and select that field which will cause the least odor problem.

If manure must be spread when odors may be a problem, immediate soil incorporation by injection or plow-down will stop the release of odors. When limited storage capacity is available, an operator may need to incorporate. With soil incorporation, less nitrogen will be lost by the volatilization of ammonia, and with larger numbers of livestock, it will be economical to incorporate. The soil incorporation break-even cost point for facilities is about 500 finishing hogs, 200 head of fed beef and 100 dairy cows when pit, tank or earthen basin storage of slurry is used.

If soil incorporation is not an option, due to cropping or soil conditions, one other alternative exists to effectively control odors. Research has shown that aerating stored liquid manure or lagoon wastewater before spreading for a period as short as four hours will remove most of the odorous compounds. Field spreading can then proceed under conditions that normally would cause an odor nuisance. The operator must realize that more odor will be released from the storage when aerating the waste, and the period selected for aerating must be such that the odors released will cause minimal nuisance. There should be wind movement in a direction other than towards close neighbors.

Many operators are choosing to use irrigation equipment for spreading manure slurries on cropland. This application method can increase odor problems unless special precautions are taken.

1. Consideration of when and where to irrigate is extremely important, as discussed previously.
2. Aerosol drift is a major concern. Odor will be transported with the aerosol. High pressure spray (80 to 100 psi at nozzle) will atomize the wastewater into finer aerosols which can travel further than larger droplets from lower pressure nozzles.
3. Lower trajectory nozzles will reduce aerosol drift.
4. A buffer zone in which no irrigating is done is recommended. A minimum width of buffer zone is 50 feet from roads and 200 feet from residences when the wind is blowing away from them. If the wind is blowing toward these areas, a much larger buffer zone is needed.
5. Windbreaks can effectively reduce aerosol drift. At least two and preferably three rows of mature trees are needed.

The operator of a manure irrigation system must also manage the system to prevent surface runoff.

Commercial Odor Chemicals: There are many compounds available with "astounding" claims as to their effectiveness in controlling and/or eliminating odors. There are four general types of chemicals. The **masking agent** is a "perfume" odor to override the offensive odor. **Counteractants** are chemically designed to block the sensing of particular odors. **Odor absorption chemicals** are reactive compounds to change the odor-causing chemical. **Biological compounds** such as enzymatic or bacterial products alter the decomposition pathway so that the odorous compounds are not generated.

There is a question as to the effectiveness of the various odor control chemicals. A study conducted at the University of Illinois with 22 commercial chemicals did not establish any of the chemicals as really effective.

It is important to test a particular odor control chemical in your facility to be certain that it does the job before purchasing large quantities. The cost range of odor control chemicals is highly variable. Liquid products are quoted at $20 to $40 per gallon and solid forms at $5 to $20 per pound. Odor control chemicals are an expensive alternative to proper design and good management. They have been used in emergency nuisance situations.

Dead Animals and Birds: The number of dead animals or birds in a confinement facility poses a different odor management problem. A specific handling procedure must be used to avoid aesthetic and odor problems. For small facilities, immediate burial where ground water pollution will not occur has been a common disposal method. There are two methods acceptable for larger facilities. The first method is incineration. The incinerator must have a second stage burner to prevent release of odors. The second method is to contract for disposal with a rendering facility. In this case, small animals or dead birds may need to be frozen until sufficient quantity is obtained to make a pick-up economical.

SUMMARY

The factors of: (1) site selection, (2) design of the manure handling and disposal system and (3) proper management can virtually eliminate odor nuisannces, even from large facilities. Until producers give as much attention to waste management as to the feeding of animals in confinement facilities, odor problems will continue to occur. In most cases, proper management will correct odor nuisance situations.

The offensiveness of odors is subjective; good public relations or "neighborliness" will go a long way in preventing odor crises. If an operator is concerned and strives to eliminate odors, a neighbor will usually not become antagonistic with infrequent odors.

SAFETY AND MANURE HANDLING

Livestock and humans have drowned in liquid manure pits or other storage structures. Manure gases have been fatal to both livestock and humans. Pigs have died after a ventilation failure in a tight building. Pigs and cattle have died when liquid manure stored in pits under slotted floors was agitated. Humans have died when they entered manure pits without first ventilating them or taking air with them in a breathing apparatus. Increased gas levels above manure pits in buildings have decreased production by slowing daily gain.

DANGEROUS SITUATIONS

The dangerous situation resulting from **manure gases** is associated with the four main gases that are produced as manure decomposes. They are listed in the table at right along with some of their characteristics. All of the gases listed here are colorless.

Characteristics of gases produced in decomposing manure and some of their effects

Gases	Odor	Density	Effects
Ammonia (NH_3)	Pungent	Lighter than air	Irritation to eyes and nose. Asphyxiating at high levels.
Carbon Dioxide (CO_2)	None	Heavier than air	Drowsiness, headache. Can be asphyxiating.
Hydrogen Sulfide (H_2S)	Rotten egg smell	Heavier than air	**Toxic:** causes headache, dizziness, nauses, unconsciousness, death
Methane (CH_4)	None	Lighter than air	Headache, asphyxiant, explosive in 5 to 15% CH_4 mixture with air.

Ammonia (NH_3) is released from fresh manure/urine and during anaerobic decomposition. Ammonia is very soluble in water so that manure collection systems that use solid floors, particularly if heated, may have more of an ammonia problem. Concentrations in ventilated hog buildings have been measured as high as 35 ppm (slightly irritating to eyes and nose) and in an unventilated building at 176 ppm (which produces extreme discomfort). At 100 to 200 ppm, ammonia causes sneezing, salivation and loss of appetite for hogs. Prolonged exposure may make pigs more susceptible to respiratory diseases.

Carbon dioxide (CO_2) is released by livestock respiration and by manure decomposition. Most of the gas in bubbles coming from stored manure or lagoons is CO_2. Death of animals in closed confinement building after the failure of ventilation equipment caused by a power failure, is due in part to excessive CO_2. Vigorous agitation of stored manure can release a "slug" of CO_2.

Hydrogen sulfide (H_2S) and other sulfides equally as toxic are produced in the anaerobic decomposition of organic wastes. Dangerous concentrations can be released by agitation of stored liquid manure. Concentrations reaching 200 to 300 ppm have been reported in a building a few minutes after starting to pump out a storage pit and have been as high as 800 ppm during vigorous agitation. Exposure to 500 ppm for 30 minutes will cause severe headache, dizziness or nausea. High concentrations of 800 to 1,000 ppm cause immediate unconsciousness and death through respiratory paralysis unless the victim is moved to fresh air and artificial respiration is immediately applied. Even the characteristic rotten egg smell of H_2S does not give adequate warning because the sense of smell is rapidly fatigued by H_2S, and high concentrations do not give a proportionately higher odor intensity.

Methane (CH_4) is generated in the decomposition of manure under strict anaerobic (no air) conditions. It is insoluble in water and lighter than air and will accumulate in stagnant air corners in the top of enclosed pits or rooms. CH_4 is not a toxic gas, but high concentrations can produce an asphyxiating atmosphere. Concentration in confinement housing is normally well below the 5 percent lower end of the explosive range. Explosions attributed to methane have occurred around manure storage pits.

Fatalities occurring when agitating manure are probably caused by compounding the asphyxiating effect of NH_3, CO_2 and CH_4 with the toxic effect of H_2S. Fatalities occurring when persons enter manure storage structures are probably due to carbon dioxide and hydrogen sulfide because they are heavier than air. Several tragic human deaths have been reported where persons entered a covered manure pit. They were instantly overcome and drowned in the remaining shallow liquid waste.

The second dangerous situation results in **drowning.** Every pit, storage tank and earthen storage basin or lagoon is a potential drowning site to adults and especially to children. Failure of slats or covers on pits have resulted in livestock death by drowning. Push-off platforms or ramps (piers) can be a site for the tractor scraper and driver to tumble into an open storage structure or lagoon. Crusts on dairy storage basins can be a problem, as they may appear capable of supporting one's weight, particularly to children.

PRECAUTIONS TO TAKE

When designing structures and systems, **think safety.** When operating or managing manure equipment, **think safety.** The following is a list of major safety points to consider in the design and operation of manure equipment, structures or systems:

1. Do not enter a manure pit unless absolutely necessary, and then only if: (1) the pit is ventilated first, (2) you have supplied air to a mask or a self-contained breathing apparatus, (3) you have on a safety harness and attached rope with **two men** standing by.
2. Properly designed and operating ventilation systems can reduce the concentration of gases within the animal zone and improve animal performance. Poorly designed or improperly adjusted ventilation air inlets may actually increase gas concentrations at the animal level.
3. Construct lids for manure pits or tanks, if at all feasible, and keep access covers in place. If an open, ground level pit or tank is necessary, put a fence around it with **keep out** sign(s).
4. Do not attempt to rescue livestock that have fallen into a manure storage structure **without assistance.**
5. Build railings alongside all walkways or piers for open manure storage structures.
6. Construct permanent ladders on the **inside** wall of all pits and tanks, even if covered. Use of non-corrosive material is important.
7. Fence in earthen storage basins and lagoons, and put up signs "Caution — Manure Storage (or Lagoon)." The fence is also needed to keep livestock away from the structure. Additional precautions include a minimum of one lifesaving station equipped with a reaching pole and a ring buoy on a line.
8. All push-off platforms or piers need a barrier strong enough to stop a slow-moving tractor.
9. When agitating manure stored in a pit underneath a building, move the animals out if possible ... otherwise (1) if building is mechanically ventilated, turn fans on full capacity when beginning to agitate, even in the winter, (2) if it is a naturally ventilated building, do not agitate unless there is a brisk breeze blowing. Watch animals when beginning to agitate and at the first sign of trouble, turn off pump. The critical areas of the building are where the pumped manure breaks the liquid surface in the pit or where the pipe to outside storage enters the building.
10. If manure storage is outside the livestock building, provide a water trap or some other device to prevent gases in the storage structure from entering the building back through the discharge pipe, especially during agitation.
11. If an animal drops over, **do not try to rescue it.** You might become a victim of toxic gases. Turn off the pump and do not enter building until gases have had a chance to escape.
12. In confined, poorly ventilated areas where methane can accumulate, don't smoke, weld or use an open flame. Maintain electric motors, fixtures and wiring near manure storage structures in good condition.
13. Keep all guards and safety shields in place on pumps, manure spreader, tank wagons, power units, etc.

Right now, review your total manure management system from a safety viewpoint. Think through each step of the collection system, storage or treatment units and the land application phase. Are there any dangerous areas in construction or operation? If so, **make them safe.** It may mean your life or the life of a loved one.

SAFETY EQUIPMENT

Locate first aid or rescue equipment near the manure storage area. Clearly mark a wall closet or box and store the equipment inside it. Make occasional checks to be sure that the equipment is in good order and has not been removed. Post the phone number of the local fire department/rescue squad on the wall beside the box and also post this number by the telephone.

Personal protective equipment including air packs and face masks, nylon lines with snap buckles and parachute type body harness with "D" rings for attaching lines can be obtained from supply sources featuring industrial safety and hygiene equipment. Look in the yellow pages under "safety," "safety equipment," "industrial safety and hygiene" or "safety supplies." These same supply sources can also provide information on monitoring or measuring devices that can be used to test hazardous atmospheres. Be sure to specify the gases you are dealing with in asking for or purchasing equipment.

IMMEDIATE FIRST AID PROCEDURES

Victims of Manure Gas Asphyxiation

1. Do not attempt to rescue a victim from a hazardous gas situation unless you are protected with a supplied air breathing apparatus.
2. Have someone telephone for an emergency medical (rescue) squad informing them that there is a "victim of toxic (manure) gas asphyxiation."
3. If the victim is free from the immediate area of danger and there is no personal threat to your life, the following steps should be taken: With the victim on his back, check for breathing. Then give four quick mouth-to-mouth breaths and check for a pulse. **If there is a pulse**, continue mouth to mouth breathing every five seconds (12 per minute). **If there is no pulse**, start CPR (cardio pulmonary resuscitation) immediately. When the emergency squad arrives, the victim should receive a high concentration of oxygen at the scene and in transport.

Victims of Drownings

1. Rescue a person from a drowning situation using the standard water rescue technique.
2. If a victim is unconscious and/or not breathing, use standard CPR procedures (See Number 3 under "Victims of Manure Gas Asphyxiation").
3. Have someone telephone for an emergency medical (rescue) squad, informing them that there is a "victim of drowning."

HANDLING ALTERNATIVES
COLLECTION, TRANSFER AND STORAGE

Components of a manure handling system include collection, storage, transport, treatment (optional) and utilization (spreading). There are many factors to consider when selecting a handling system for a specific operation, including livestock type, age and size, feed, housing, bedding, cropping, topography of farmstead, proximity to waterways, proximity to neighbors and preference of farmer. Therefore a handling system, at least in part, needs to be fitted to each livestock operation.

This section will present different types of equipment and structures for the handling of livestock manures, considering the factors listed above. Systems for handling liquid (slurry) and solid manure are discussed for the major livestock types. Runoff control facilities are essential with open feedlots (see section "Feedlot Runoff Control"). Proper management is the key to operating a handling system satisfactorily.

In most facilities, some method for providing manure storage is needed. The value of a storage structure is to provide flexibility for scheduling field spreading to avoid wet ground, growing crops or conditions conducive to causing pollution. The storage must be designed to minimize rainfall runoff and odor nuisance potential. The volume of storage must provide for accumulated manure, bedding, wash water or dilution water, as the case may be, for the period that such wastes cannot be disposed of. A covered manure structure, though higher in cost, may be practical due to improved handling conditions and less bedding, as in the case of dairy. Design details for equipment and structures may be found in the Midwest Plan Service publications.

DAIRY

In Figure 1, the components of "solid" and "liquid" manure systems for dairy are presented. The basic decision is whether to go with a liquid or a solid system. Another consideration is handling rainfall runoff from barnlots. Procedures for handling runoff are discussed in the section "Feedlot Runoff Control."

Solid Handling

Alternatives for handling dairy manure in a solid form are listed in Figure 1. Many existing dairy operations use solid handling. Solids storage is best provided with an above ground structure. Figures 2 and 3 show various equipment for collecting manure and two types of above ground solids storage structures. The picket dam structure for storing manure is shown in Figure 4. The vertical slots in the plank fence allow rainwater runoff to drain away. The manure will then not absorb the rainwater and become more "soupy." So in most cases, it can be handled as a solid, in a box or flail spreader. Figure 5 shows a recently developed storage system for transferring and loading out manure by gravity. A terrain sloping 10 percent away from the barn for 250 to 300 feet can provide the necessary head for both filling and emptying the storage facility by gravity.

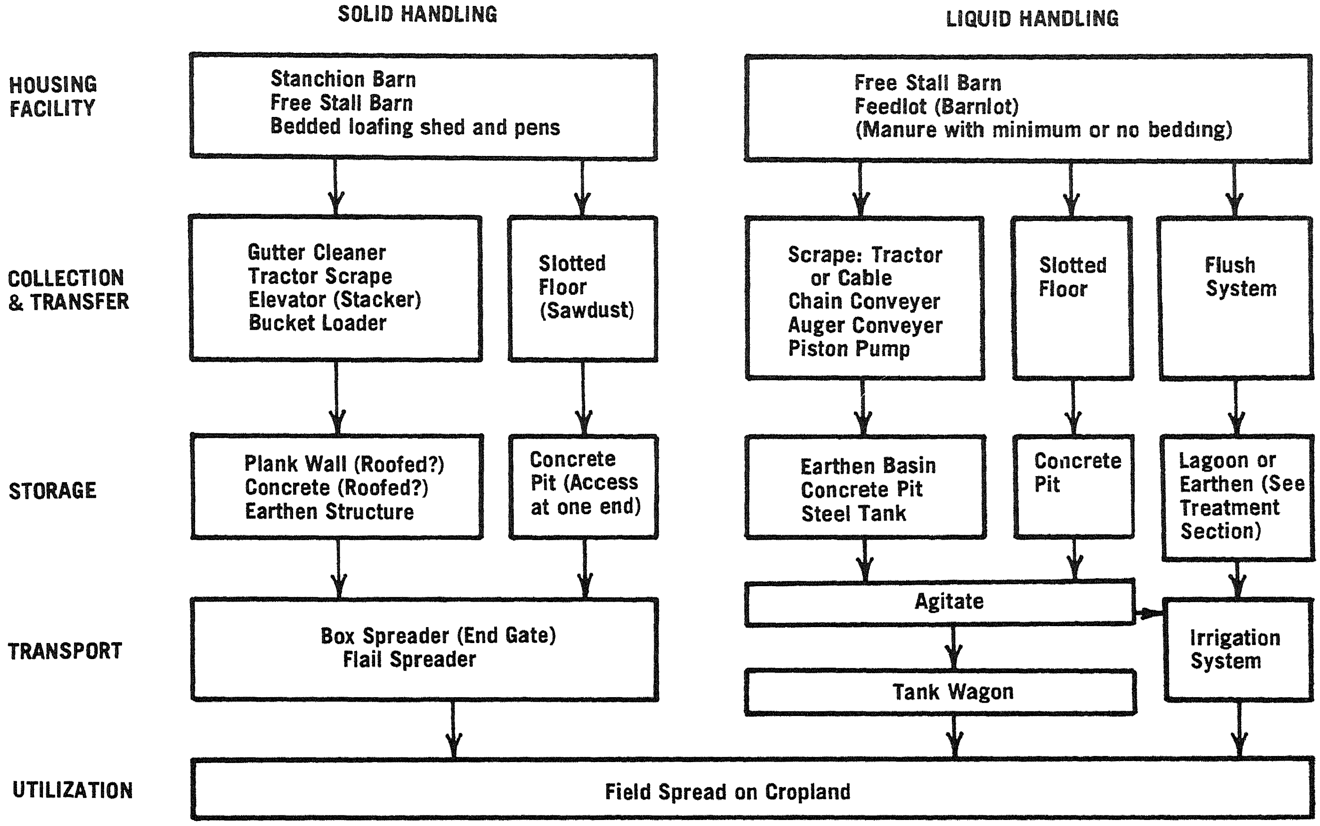

Fig. 1: Handling alternatives for dairy manure

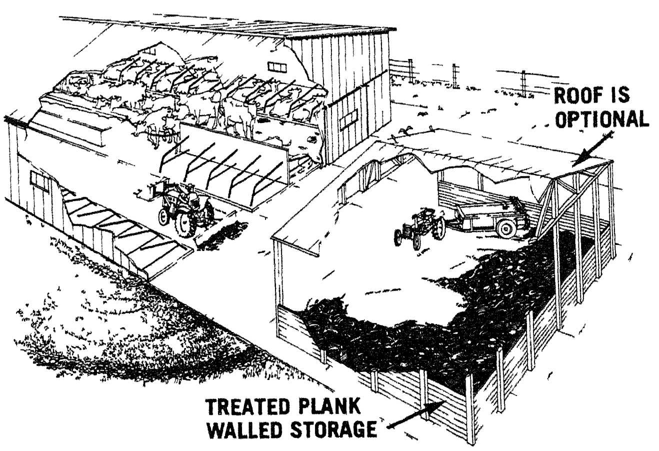

Fig. 2: Free stall dairy barn with tractor scrape, upground plank walled storage and box spreader for solid handling.

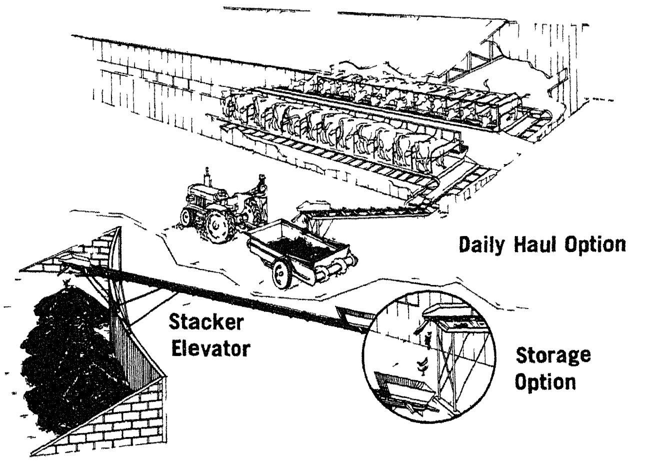

Fig. 3: Confinement dairy barn with conventional gutter cleaner or elevator (stacker) and concrete pad storage.

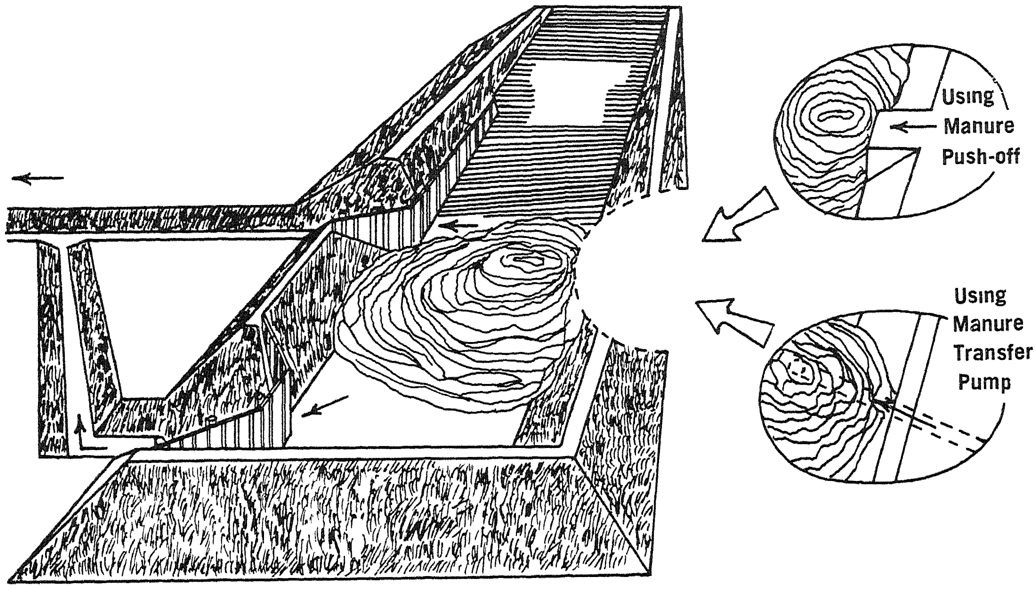

Fig. 4. Picket-dam manure storage (Pickets allow rainwater runoff to drain away . . handle manure in solid form).

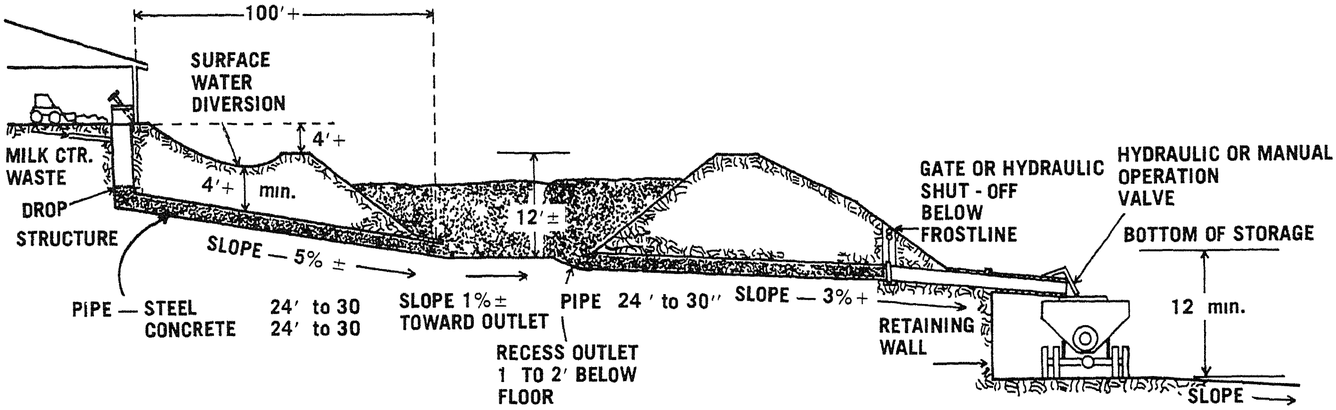

Fig. 5: Gravity system for transferring, storing and loading-out manure (Courtesy, R. W. Guest, Agricultural Engineering Department, Cornell University, Ithaca, N.Y.)

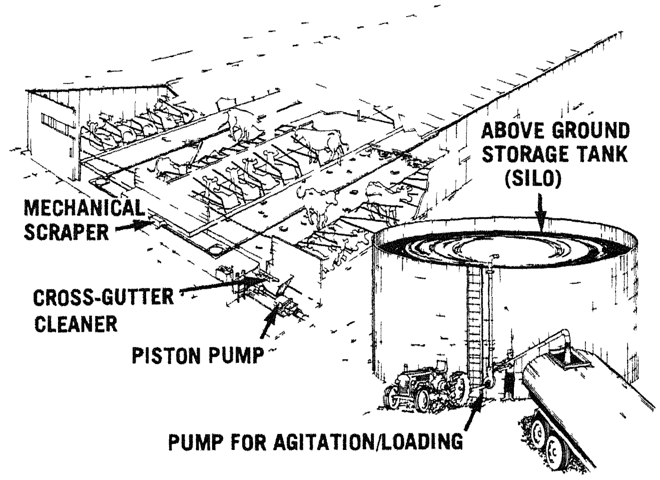

Fig. 6: Free stall dairy barn with mechanical alley scraper, crossgutter cleaner, piston pump and upground storage tank.

Liquid Handling

Most new dairy facilities are using free stall housing with liquid manure handling. The basic methods of collecting manure from a free stall barn are noted in Figure 1. Depending on the method of collection, the manure may be stored in earthen basins or above ground tanks. Figures 6, 7 and 8 show various collection, storage and transport methods for liquid manure.

The piston type pump, shown in Figures 6 and 8, provides a convenient method of transporting manure to a storage structure. A key factor in the design of any liquid storage structure is provision for agitating the waste prior to loading the tank wagon or irrigating. Without complete agitation, solids will accumulate in the structure and reduce the storage capacity. Above ground metal or poured concrete circular tanks offer a slight advantage over earthen ponds, regarding agitation and ease of loading tank wagons.

Undiluted manure from cattle, when placed in a storage structure, usually will develop a crust of floating solids. This crust will help to control odors and should not be disturbed until the waste is agitated just prior to field spreading.

The principal advantage of the flush system for col-

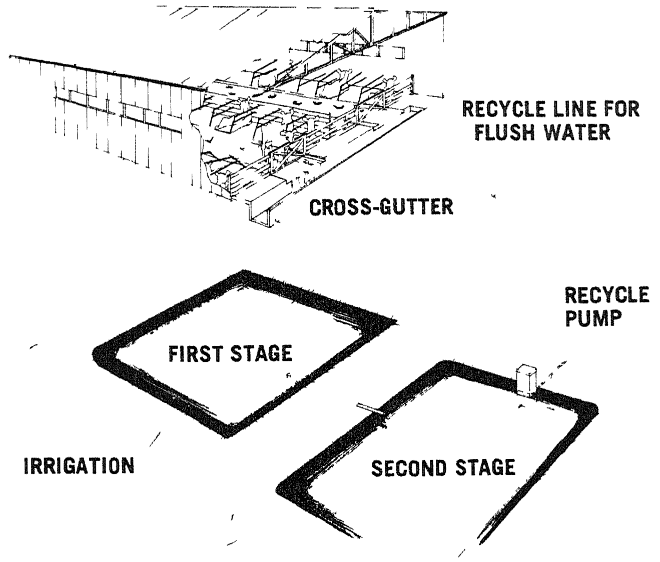

Fig. 7: Flushing free stall alleyways to a two-stage lagoon treatment system.

lecting manure is that it can be automated. In order to minimize the amount of water to be field spread, some means of recycling clarified waste water for flushing is needed. Because of the quantity of water used in a flush system, some form of sprinkler irrigation for land application is recommended for final disposal.

Milk Sanitation Constraints

There are some special factors to consider in a dairy waste management system to meet milk sanitation requirements. The system should be designed and managed so as to:

(1) Prevent the soiling of the cows' flanks, udders, bellies and tails;
(2) reduce or prevent the breeding of flies; and
(3) prevent the contamination of potable water supplies.

Manure packs accessible to animals must be solid to the footing of the animals. The cowyard shall be graded and drained and have no standing pools of water or accumulations of organic waste. Approaches to the barn door(s) and the area surrounding stock watering and feeding stations must be solid to the footing of the animals. Dairy management must be directed toward eliminating overcrowding of cowyards and housing areas.

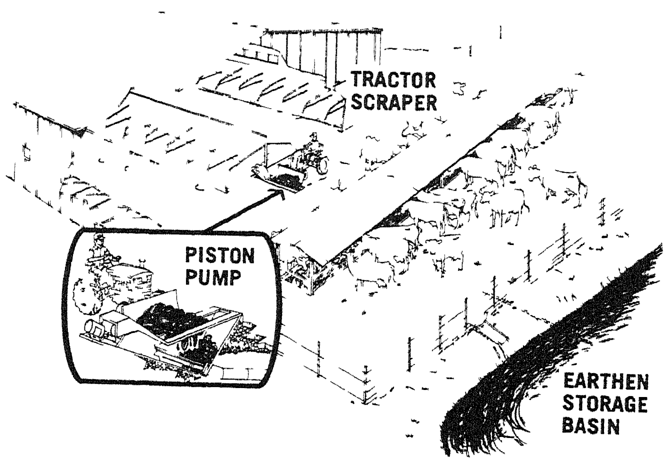

Fig. 8: Free stall dairy barn with tractor scraper, piston pump and earthen storage basin waste system

BEEF

The handling alternatives for beef cattle manure are also divided into liquid and solid handling, as shown in Figure 9. In Ohio the typical cow/calf beef operation houses the cattle during winter and early spring. In most cases, the housing for cow/calf operations utilizes a solid handling system. A solid handling system for feeders is commonly used for small operations where bedding is available. Where partial housing and open barnlot is used, the lot area must be scraped regularly to a storage structure, as shown for dairy in Figure 2, or field spread directly. Wherever there is an open lot, rainfall runoff control structures must be provided, (see section, Feedlot Runoff Control). Many existing barnlots are unpaved, but paved lots are recommended as manure collection and runoff control can be more easily provided.

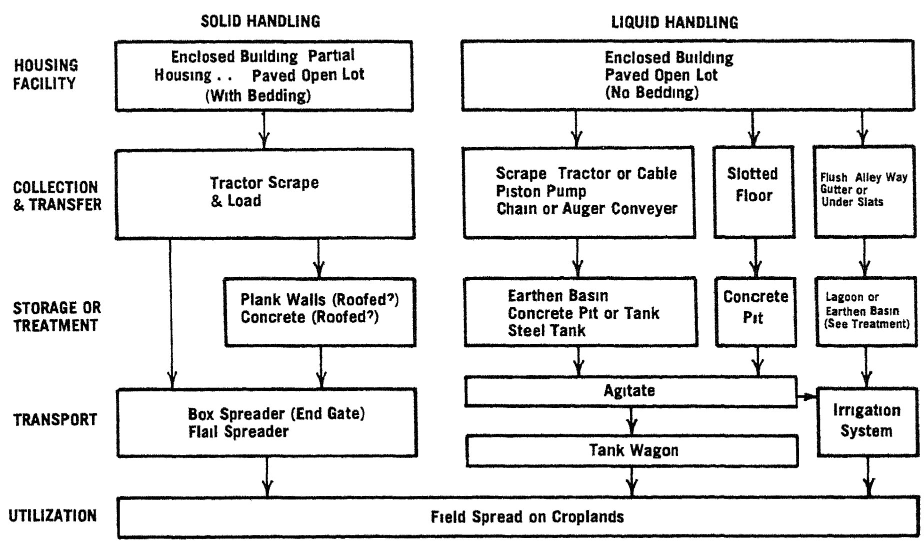

Fig. 9: Handling alternatives for beef manure

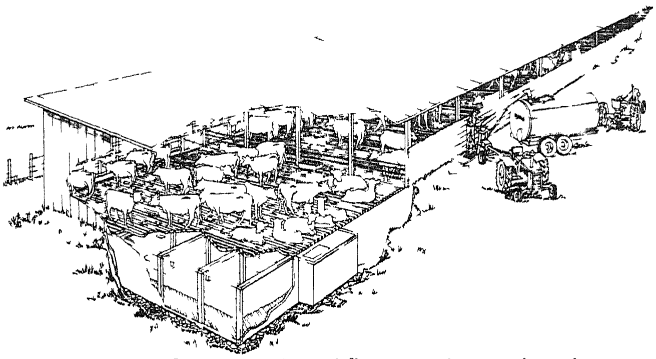

Fig. 10: Total confinement, slotted floor, pit storage, liquid manure handling system.

Liquid manure handling alternatives, listed in Figure 9 for a beef feeding operation, are best used in a confined feeding operation. The collection methods and type storage must be selected together. Figure 10 shows a beef liquid handling system where slotted floor and pit storage is used.

Beef facilities may have liquid handling components and structures similar to those of dairy shown in Figures 6 and 8.

SWINE

The trend in swine waste handling is toward liquid systems because they are labor saving and lend themselves to automation. In the handling alternatives for swine manure in Figure 11, the liquid systems are subdivided into undiluted and diluted. The diluted waste undergoes some form of treatment. Undiluted swine wastes agitate readily and can be pumped. When swine manure is handled in the solid form, more labor is involved. Where partial housing and open lots are used, provision must be made to handle the runoff, and solid storage is usually used.

A primary consideration in swine waste handling is to minimize the odor nuisance. Under slat, pit ventilation may be used to reduce the odors and gases within the confinement building. If the waste is removed from the building soon after it is voided, there will be much less odor and gases in the building. The narrow gutter, gravity discharge system, shown in Figure 12, can be drained every second or third day to a tank or pond storage outside the building. A complete description of the narrow gutter system is found in Ohio Cooperative Extension Service Factsheet, AEX 702.

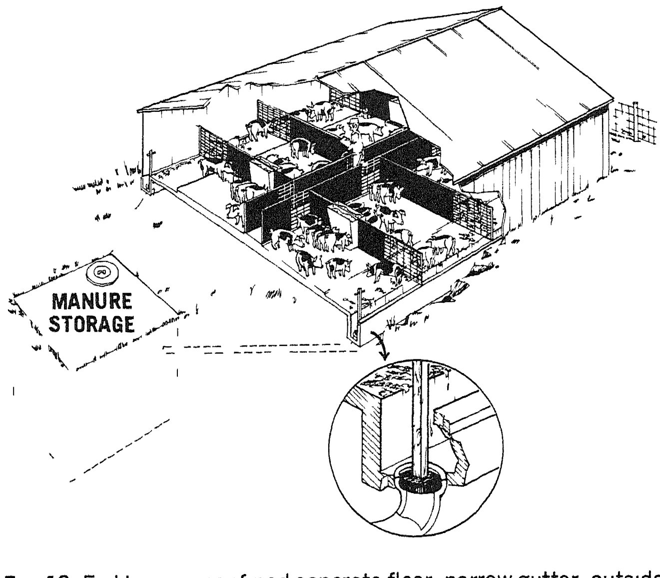

Fig. 12: Fed hogs — confined concrete floor, narrow gutter, outside storage, liquid handling.

A flushing gutter system with a shallow dunging channel about three inches deep and three to five feet wide may be used. Flushing may also be done beneath slatted floors. Flushing water may be released from a tip tank or an automatic dosing siphon. Slopes of floors and flushing channel, flushing equipment and other design details may be found in the Livestock Waste Facilities Handbook, MWPS-18.

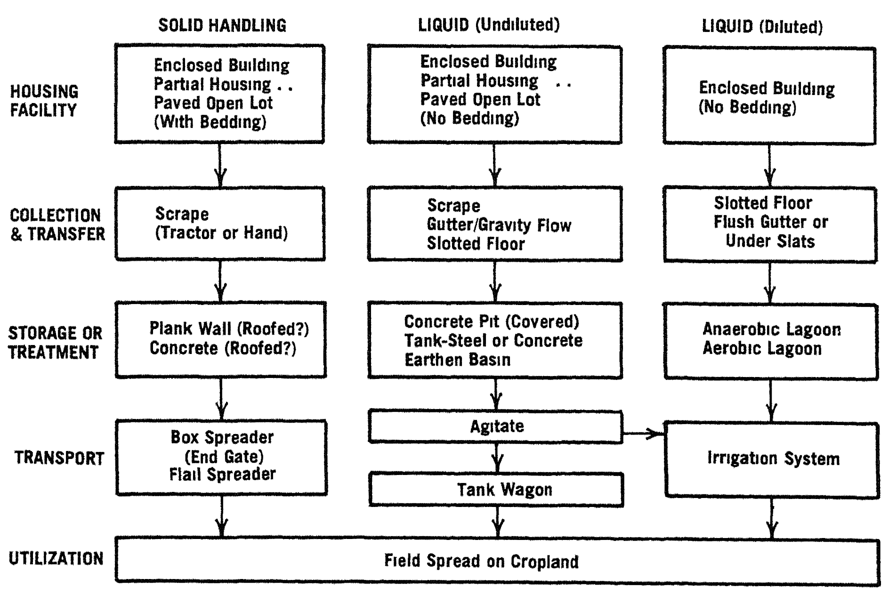

Fig. 11: Handling alternatives for swine manure

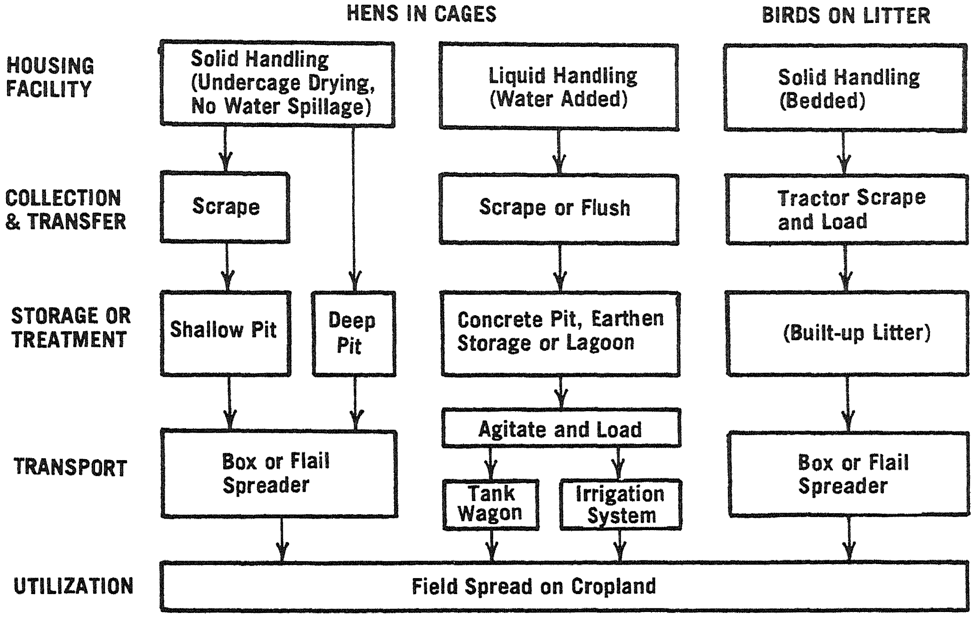

Fig. 13. Handling alternatives for poultry manure

POULTRY

Poultry manure has a higher total solids content than most other manures. Diluting it with water increases the odor nuisance potential; therefore, handling it as a solid is usually preferred. Handling alternatives for both hens and broilers are presented in Figure 13. Most hens are fed in cages and most broilers are raised on litter. In order to handle caged layer manure in the solid form, no drinking water leaks can be allowed. A drier manure can be obtained with under cage circulation of air and under cage exhaust of air from the building. There is commercial equipment available for scraping and removing the manure from beneath cages. When a deep pit is used to provide one or more years of storage, a tractor loader can be used to clean out the pit, as shown in Figure 14.

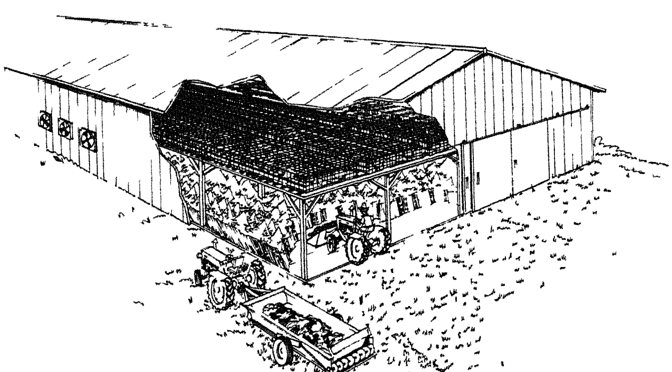

Fig. 14: Caged layer "higher-rise" house. Manure accumulates for one or more years.

HORSES

Horse manure is best handled as a solid. Because of the individual stabling of the horse, manual cleaning of the stalls is common. Where a large number of horses are stabled together, a conveyer system to move the manure from the building will lower the labor requirement. A covered manure storage structure will provide flexibility in scheduling field spreading and avoid rainfall runoff problems.

SHEEP

Sheep are most commonly housed in bedded pens with a manue pack. Construction of housing should allow for cleaning out the manure with a tractor loader. Sheep may be raised on slats or expanded metal floors, which allows the manure to pass through to a pit beneath. The manure can be removed with a cable scraper and stored in a covered structure prior to field spreading.

MANURE CHARACTERISTICS

Table 1: Manure Production[1]

	Size	Total Manure Production		Solids		VS	BOD_5	Nutrient Content[2]					
Animal	Pounds	cu ft/day	gal/day	%	lb/day	lb/day	lb/day	lb N/day	lb P/day	lb K/day	lb N/yr	lb P/yr	lb K/yr
Dairy Cattle	150	0.19	1.5	12.7	1.6	1.3	0.26	0.06	0.010	0.04	22	4.0	15
	250	0.32	2.4	12.7	2.6	2.1	0.43	0.10	0.020	0.07	37	6.7	25
	500	0.66	5.0	12.7	5.2	4.3	0.86	0.20	0.036	0.14	75	13	49
	1000	1.32	9.9	12.7	10.4	8.6	1.70	0.41	0.073	0.27	150	27	99
	1400	1.85	13.9	12.7	14.6	12.0	2.38	0.57	0.102	0.38	210	37	138
Beef Cattle	500	0.50	3.8	11.6	3.5	3.0	0.80	0.17	0.056	0.12	62	20	44
	750	0.75	5.6	11.6	5.2	4.4	1.2	0.26	0.084	0.19	93	30	66
	1000	1.0	7.5	11.6	7.0	6.0	1.6	0.34	0.11	0.24	124	40	88
	1250	1.2	9.4	11.6	8.7	7.4	2.0	0.43	0.14	0.31	155	50	110
Cow		1.05	7.9	11.6	7.3	6.2	1.7	0.36	0.12	0.26	131	44	95
Swine													
Nursery pig	35	0.038	0.27	9.2	0.20	0.17	0.07	0.016	0.0052	0.010	5.7	1.9	3.8
Growing pig	65	0.070	0.48	9.2	0.39	0.31	0.13	0.029	0.0098	0.020	11	3.6	7.1
Finishing pig	135	0.15	1.10	9.2	0.81	0.65	0.26	0.060	0.020	0.040	22	7.3	14.6
	150	0.16	1.13	9.2	0.90	0.72	0.30	0.068	0.022	0.045	25	8.2	16
	200	0.22	1.5	9.2	1.2	0.96	0.39	0.090	0.030	0.059	33	11	22
Gestate sow	275	0.15	1.1	9.2	0.82	0.66	0.27	0.062	0.021	0.040	23	7.7	15
Sow & litter	375	0.54	4.0	9.2	3.0	2.4	1.0	0.23	0.076	0.15	84	28	55
Boar	350	0.19	1.4	9.2	1.0	0.84	0.35	0.078	0.026	0.051	28	9.5	19
Sheep													
Lamb	80	0.05	0.37	25	0.8	0.68	0.07	0.036	0.0053	0.026	13	1.9	9.5
Ewe	140	0.09	0.65	25	1.4	1.2	0.13	0.063	0.0092	0.045	23	3.4	16.4
Poultry[3]													
Layers	4	0.0035	0.027	25	0.053	0.037	0.014	0.0029	0.0011	0.0012	1.05	0.41	0.45
Broilers	2	0.0024	0.018	25	0.036	0.025	0.0023	0.0024	0.00054	0.00075	0.85	0.19	0.26
Turkeys	11	0.0083	0.062	25	0.13	0.09	0.013	0.06	0.0023	0.0036	2.23	0.86	1.33
Ducks	4	0.006	0.050	20	0.072	0.05	0.005	0.005	0.0011	0.0015	1.83	0.40	0.55
Horse	1000	0.75	5.6	21	9.4	7.5	6.5	0.27	0.046	0.17	99	17	62

[1] Source: Agricultural Engineers' Yearbook, ASAE D384, December 1976 and MWPS-18, Livestock Facilities Handbook
[2] P = 0.44 P_2O_5 and K = 0.83 K_2O
[3] Excreta of birds; not mixed with bedding or water

The first step in designing a manure handling system is to know how much and what kind of waste will be involved. Table 1 lists manure production data and characteristics for typical livestock weights. The values listed are average values and some variation can be expected due to animal age, feed ration, type of confinement, method of manure handling, etc. The volatile solids (VS) data is used in designing lagoons. The BOD data is used in designing aerobic treatment systems.

The amount of nutrients per quantity of manure given in Table 2 is for fresh manure and urine. Nutrient losses that occur in handling, storage and spreading are given in the section on Land Application.

The volume of manure produced is used to calculate storage volumes. Selection of manure handling equipment is related to the solids content. Manures containing less than 15 percent TS (or more than 85% water) will be a slurry when mixed, and can be handled as a "liquid." Generally, if the TS is greater than 15 percent, as when bedding is added or drying occurs, the manure is handled as a solid.

Table 2: Nutrients in manure (without storage and handling losses)

	Element (lb/1000 gal manure)			Element (lb/ton raw manure)		
	N	P	K	N	P	K
Dairy	41	7.4	27	9.9	1.8	6.6
Beef	45	15	32	11.4	3.7	8.4
Swine	55	18	32	13.8	4.6	9.0
Sheep	97	14	69	22.5	3.3	16.0
Layer	109	42	47	27.2	10.6	11.6
Broiler[1]	—	—	—	34.3	7.6	10.6
Horse	48	8	30	12.1	2.0	7.5

[1]Birds on litter.

Bedding is used in most solid waste handling systems. Table 3 gives characteristics of common bedding materials as related to water absorption and fertilizer nutrients. This information should be used in calculating nutrient value of manure for land application when bedding is used. An estimate of the bedding used can be obtained by measuring the amount used for a small number of animals and extending it to the whole herd. The volume of bedding is reduced in the manure to about one-half of its dry volume. The total volume of manure will then equal the volume of manure from Table 1 plus one-half of the volume of the dry bedding used. The Livestock Waste Facilities Handbook (MWPS-18) discusses in detail the amount of bedding required to thicken manure. Also, it discusses the amount of water needed to dilute manure so that it can be pumped.

Table 3: Characteristics of common bedding materials

Material	Lb. Water Absorbed per lb. Bedding[1]	Density (lb/cu ft)	Air Dry Composition of Materials (lb per ton) N	P_2O_5	K_2O
STRAW					
Wheat (baled)	2.2	5-7	11	4	20
Oats (baled)	2.5	7-8	12	4	26
CORNSTALKS					
Shredded	2.5	4-5	15	8	18
HARDWOOD,					
Shavings or Sawdust	1.5	9-12	4	2	4

[1]Typically 10% moisture content.

LAND APPLICATION

Application of animal wastes on land is an efficient disposal alternative because of the lower costs usually associated with land application and the benefits derived by the crop from the nutrients in manure. There are two principal objectives to meet in applying animal waste on land: maximum utilization of the manure nutrients by crops and minimizing the water pollution hazard. In order to meet these objectives, several factors should be taken into account in developing a manure application plan. These include:

1. **Characteristics of manure:** The amount of plant-available nutrients in the manure, especially nitrogen, will determine the application rate.
2. **Number of animal units and land available for application:** This will determine the amount of manure produced and the frequency and rate of manure application.
3. **Type of crops and rotation:** The rate, time and method of application will depend on the types of crops to be grown and the crop rotations used.
4. **Topography of application area:** Slope of the land and position relative to farm ponds, drainage ditches and streams will determine the potential nutrient loss and pollution hazard.
5. **Time of year:** Crop cover, form of precipitation, winter application on snow or frozen ground will affect nutrient loss and potential water pollution.

FACTORS CONTROLLING APPLICATION RATE

The factor that most often limits the amount of manure that should be applied to crop land is nitrogen. All manure contains appreciable amounts of nitrogen, and levels greater than the nitrogen requirements of the crop may lead to nutrients entering surface waters or leaching into groundwater. The amount of nitrogen produced in manure varies with the type and size of animal (Tables 1 and 2). The amount that finally gets into the soil depends on the nitrogen losses due to storage, handling and spreading (Table 4).

In order to maximize nitrogen utilization by the crop and reduce pollution, the available nitrogen in manure should not exceed the nitrogen requirements of the crop. This will depend on the type of crop and the yield goal. This information can be obtained from the Agronomy Guide (Ohio State University Cooperative Extension Service, Bulletin 472).

Only about one-third of the nitrogen in animal manure, except poultry, is available to crops in the year in which it is applied, and the remaining two-thirds, residual organic nitrogen, becomes part of the soil organic matter. It is mineralized or becomes available at the rate of about five percent a year. In the case of poultry waste, about 75 percent of the nitrogen is available the first year and the remainder also mineralizes at about five percent annually. In order to determine how much nitrogen will be available to crops from manure applications, the grower must take into account the mineralized nitrogen that will become available from previous manure applications, given in Figure 15. Examples for calculating crop requirements are given at the end of this section.

Manure is also a good source of phosphorus and potassium. After the manure application rate has been determined with respect to nitrogen, the amount of phosphorus and potassium that will be available from the manure can be calculated from Table 1 or 2. All of the phosphorus and potassium in manure will be available to the crop in the year it is applied, except as noted in Table 4.

Table 4: Percent Nutrient Losses Under Various Management Systems

Management System	Loss of Nutrient: Nitrogen[1] %	Phosphorus %	Potassium %
Solid Handling			
1. Bedded building, regularly surface spread	40	—	—
2. Manure pack, surface spread	50	—	—
3. Confined housing, daily scraped and surface spread	40	—	—
4. Open paved lot, scrape, 6 mo. storage, surface spread	60	30	25
5. Poultry pit under cages, surface spread	50	—	—
Liquid Handling			
6. Pit, earthen basin or above ground storage, surface spread	40	—	—
7. Anaerobic lagoon, surface spread	80	50	40
8. Aerobic (aerated) lagoon, surface spread	40	30	25

[1]It is ammonia nitrogen that is lost. Injection or immediate soil incorporation will decrease loss, saving from 20 to 25 percent of the nitrogen.

If the grower has applied phosphorus and potassium over the years, the soil test levels may be in the adequate to high range. Additional amounts applied in manure are not likely to become a pollution problem because they are held tightly by the soil particles. However, if the grower is able to supply some nitrogen as chemical fertilizer, it would be more economical to apply manure at rates that would satisfy the potassium and/or phosphorus needs of the crop. This can be determined in the same manner as for nitrogen in the examples, the only difference being that all of the potassium and phosphorus in the manure is assumed to be available in the year it is applied. It should be noted that manure contains much more potassium than magnesium or calcium, and after many years of continued manure application, the ratio of potassium to magnesium and calcium may be too high for optimum crop growth. Additional magnesium and/or calcium may have to be added as dolomitic or calcitic limestone to adjust the ratio. The soil should be tested regularly to determine the levels of these nutrients. If a mineral imbalance is suspected, plant tissue analysis should be made to determine the extent of the problem.

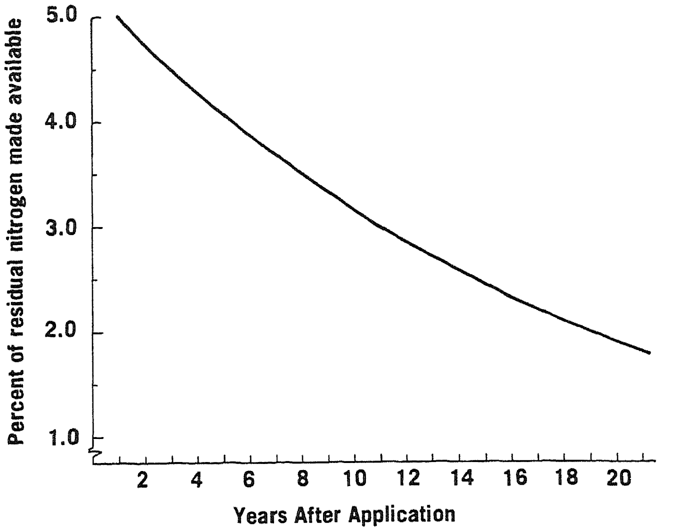

Fig. 15: Percent of residual organic nitrogen made available from manure applied in previous years.

Time of application

Manure is best applied when it can be incorporated as soon as possible. This means prior to plowing or tillage. Manure can be spread without incorporation in the fall or spring on ground with sod cover or crop stubble to retard runoff. When necessary to spread on frozen, sloping, snow covered ground, spread on the least sloping ground with good vegetative cover away from streams and drainageways. This will assure maximum conservation of nutrients for crop production and minimize the pollution potential.

Sample calculations of manure application rates:

Example 1 — Manure from 60 dairy cows has been applied every year for five years (except two years ago when none was applied on this field) to a 30-acre field that will be in field corn this year. The yield goal is 160 bushels per acre. According to the Agronomy Guide, the nitrogen (N) application rate should be 200 pounds per acre. If each cow weighs 1400 pounds, the pounds of nitrogen excreted by each cow is 210 pounds per year (Table 1). Therefore, total nitrogen excreted per year for the 60-cow herd equals:

$$60 \text{ animals} \times 210 \text{ lbs. N/animals each day} = 12{,}600 \frac{\text{lbs. N}}{\text{yr.}}$$

According to Table 4, and assuming that storage and handling approximates system Number 2, the nitrogen remaining after accounting for these losses will equal:

$$0.50 \times 12{,}600 \text{ lbs. N} = 6300 \text{ lbs. N}$$

Nitrogen in the manure will be applied to 30 acres to give:

$$\frac{6300 \text{ lbs, N}}{30 \text{ acres each yr.}} = \frac{210 \text{ lbs. N}}{\text{acre each yr.}}$$

Of this nitrogen, one-third will be available to the corn crop this year and this equals:

$$0.33 \text{ each yr.} \times \frac{210 \text{ lbs. N}}{\text{acre each yr.}} = \frac{70 \text{ lbs. available N}}{\text{acre}}$$

To determine how much available nitrogen is contributed from previous applications, Figure 15 is used. This figure gives the percentage of the residual nitrogen from previous applications that is available this year. This residual nitrogen is mineralized (becomes available) at a rate of 5 percent per year, but with each succeeding year, the remaining residual N decreases. Therefore, the percentage in Figure 15 decreases. For this example, the residual nitrogen from each of the previous applications, except two years ago, is equal to the total nitrogen application rate minus the one-third that is available this year (which is the same as for the present year):

$$\text{Residual N} = 210 - 70 = 140 \frac{\text{lbs. N}}{\text{acre}}$$

The percentage of this residual nitrogen application available from each previous application would be from Figure 15.

$$140 \frac{\text{lbs. N}}{\text{acre}} \left(\frac{4.1 + 4.3 + 4.5 + 0.0 + 5.00}{100}\right) = 25 \frac{\text{lbs. N}}{\text{acre}}$$

The total nitrogen available from previous and the current manure application then equals:

$$70 + 25 = 95 \frac{\text{lbs. N}}{\text{acre}}$$

Additional nitrogen required to meet the requirements of the crop equals:

$$200 - 95 = 105 \frac{\text{lbs. N}}{\text{acre}}$$

The phosphorus available in manure applied this year equals (Table 1):

$$\frac{37 \text{ lbs. P}}{\text{animal each yr.}} \times 60 \text{ animals} = 2220 \frac{\text{lbs. P}}{\text{yr.}}$$

On 30 acres, the P_2O_5 per acre would be:

$$\frac{2220 \text{ lbs. P}}{30 \text{ acres}} = \frac{74 \text{ lbs. P}}{\text{acre}} - 0.44 = 168 \frac{\text{lbs. } P_2O_5}{\text{acre}}$$

According to the Agronomy Guide, if the phosphorus soil test is between 30 and 60 pounds P per acre, the annual phosphate application should be 60 pounds P_2O_5 for 160 bushel corn per acre. Since the manure supplies 168 pounds P_2O_5 per acre, no additional phosphate is needed. The grower may apply manure at a rate to meet phosphorus needs by using more acreage and supply additional nitrogen as a chemical fertilizer.

Potassium requirements can be determined in the same manner.

Example 2 — A swine operator maintains a 300-head herd. He has a liquid waste system with a holding capacity of six months. He plans to apply his manure on his corn crop, half in the fall before plowing and the other half in April just before planting. He needs to calculate how much nitrogen from the manure will be available to the corn (50 acres). The average weight of his herd is 150 pounds. The amount of nitrogen excreted (Table 1) is:

$$\frac{0.068 \text{ lbs. N}}{\text{animal day}} \times 300 \text{ animals} \times 182 \text{ days} = 3710 \text{ lbs. N}$$

After storage and handling losses are considered (Table 4), only 60 percent of the nitrogen remains, and this equals:

$$0.60 \times 3710 \text{ lbs. N} = 2230 \text{ lbs. N}$$

One-third of the manure N applied in the current year will be crop-available; this will give:

$$0.33 \times 2230 \text{ lbs. N} = 730 \text{ lbs. crop-available N with each application}$$

Assuming the same rate of manure was applied in the previous two years, the residual nitrogen each year would be:

$$2230 \text{ lbs. N} - 730 \text{ lbs. N} = 1500 \text{ lbs. N}$$

From Figure 15, we determine the percentage of residual N mineralized to available N from the previous two years applications:

$$1500 \text{ lbs. N} \left(\frac{4.75 + 5.00}{100}\right) = 150 \text{ lbs. N}$$

The total crop-available N from current and previous applications then will be:

$$(730 + 150) = 880 \text{ lbs. crop-available N}$$

The same amount of manure will be applied twice to the same land (fall and spring), and this will give a total crop-available N of:

$$2 \times 880 = 1760 \text{ lbs. N.}$$

It is apparent that this is a small amount of nitrogen for 50 acres and will not contribute much to the N requirements of the corn crop. The operator can safely apply his manure on a much smaller acreage without exceeding N utilization by the crop.

However, this 300-hog herd will produce 2460 pounds P per year (5600 lbs. P_2O_5 per year) and 4800 pounds K per year (5800 lbs. K_2O per year). According to the Agronomy Guide, there will be enough P_2O_5 for 90 acres of corn (160 bushels per acre). A typical K_2O application of 45 pounds per acre will allow enough K_2O for 125 acres. Applying the manure at the P or K rate, supplying additional commercial nitrogen and utilizing more acres would be more economical.

IRRIGATION OF MANURE SLURRY AND WASTEWATER

Irrigation equipment has been adapted to the disposal of liquid manure and wastewaters on cropland. The primary concern is to dispose of the wastes in an environmentally acceptable manner. The application criteria is determined by the hourly and the annual application rate. The hourly application rate is controlled to prevent runoff by having the irrigated wastewater infiltrate into the soil.

The maximum annual application rate is controlled by the nitrogen applied to the soil. The timing of applications is dictated by the accumulated volume of waste, availability of land area and soil/climatic conditions.

The use of manure or wastewater for "true" irrigation is seldom accomplished because of the relatively small volume and the annual application rate restriction. If one wants to irrigate in addition to spreading manure, be certain that there is an adequate supply of water available for irrigating. Manure slurries from pit, tanks or storage basins should not be irrigated on growing crops. Such manures, high in ammonia, will burn vegetation. Wastewater in lagoons is normally dilute enough to allow irrigation on growing crops.

ADVANTAGES TO USING IRRIGATION

(1) Large amounts of effluent can be spread in a relatively short time, e.g. 1 acre-foot of liquid waste (326,000) gals.) can be spread in 24 hours with a 225 gallon per minute sprinkler but will require 220 trips with a 1,500 gallon manure tank wagon.
(2) Waste effluents can be used to supplement irrigation water and to supply plant nutrients where regular irrigation of crops is practical.
(3) Irrigation may cost less than other methods to install, usually are cheaper to operate and require less labor for equivalent volumes of application.
(4) A high degree of automation is possible with some types of irrigation equipment.
(5) Manure guns (nozzles) can handle slurry directly from confinement and washdown operations.
(6) Disposal can often be accomplished when moist soil conditions prohibit conventional hauling. However, do not irrigate on saturated soil as runoff will occur.
(7) Less soil compaction occurs with irrigation than with tank wagons.

DISADVANTAGES TO USING IRRIGATION

(1) An adequate application area may not be within economical pumping distance ofthe waste source.
(2) Odors and spray drift (aerosols) can be problems, depending on location and management.
(3) Additional water supply and/or large storage basins may be required for dilution, flushing the equipment, and a safe, efficient use of wastewater.
(4) Runoff is a potential pollution hazard.
(5) Without good management, annual application of nutrients may be excessive and cause nitrate pollution in groundwater.

EQUIPMENT AND SYSTEMS

Basic irrigation equipment needed is:
(1) Hi-pressure irrigation pump
(2) Suction line
(3) Pipe (portable) to application area
(4) Nozzle and stand
(5) Pump for agitating storage waste

Four main types of irrigation systems are being used for wastewater disposal:
(1) Hand moved (portable pipe) — up to 1.5 acre per set
(2) Traveller with hose drag — up to 7.0 acres per set
(3) Traveller with hose reel — up to 12 acres per set.
(4) Mobile center pivot (one tower) — 10 acres per turn

Manure slurries should be less than 10 percent total solids when using irrigation equipment. Most manure in storage meets this criteria and water can be added for dilution. When using "big gun" nozzles, the pressure should be 80 to 110 psi at the nozzle. Small irrigation pumps can deliver 200 to 400 gallons per minute. Large irrigation pumps deliver 400 to 1000 gallons per minute.

Pipelines used in waste management systems can be of the same type and general design used in normal irrigation systems. Because of the corrosiveness of the wastewater, underground pipelines should be constructed of plastic or asbestos cement pipe. If possible, clear water should be used for flushing pipelines and other waste disposal equipment after each use, but definitely before storage.

APPLICATION RATES

The hourly application rate should be matched to the infiltration rate of the soils. If the hourly application rate is excessive, there is danger of polluting surface waters or flooding adjoining areas with runoff. The design application rate should be conservative and usually lower than the maximum allowable rate in the Ohio Irrigation Guide, because in time, the soil intake rate may be reduced because of the solids and salt content in some wastes. The amount applied at any one time must not exceed the holding capacity of the soil at the time of application.

The annual application rate at any one site must not exceed the annual nitrogen needs of the crop. The criteria discussed in the section on Land Application are valid for irrigation of manure and wastewater.

OPERATION AND MAINTENANCE

The nature of manure disposal contributes to the tendency on the part of many operators to wait until holding facilities are full or overflowing before emptying them. Poor management of waste disposal by irrigation has resulted in pollution and dissatisfaction with the system.

Some good management guidelines are:
(1) Irrigate wastes per schedule in the waste management plan.
(2) Do not irrigate when it is raining or on saturated soils.
(3) Be alert to potential odor problems. Select site and time of irrigation that will minimize odor nuisance. (See section on Odor Control.)
(4) Keep debris out of manure and wastewater.
(5) Follow the equipment manufacturer's recommended maintenance program.
(6) If possible, flush pumps and other irrigation equipment with clear water after each use to help prolong their life.
(7) Fill underground pipelines with clear water before using them to help eliminate dead spots of solids.

ECONOMIC IMPACTS

High rates of inflation have resulted in rapidly rising capital and labor costs. Recent price increases in commercial fertilizers have led producers to closely examine the use of manure as substitutes for commercial fertilizers.

This section is presented to permit a producer to readily assess the economic impacts of alternative waste handling systems designed to reduce pollution. Capital, labor and feed requirements are summarized for several typical waste disposal systems for dairy, beef and swine enterprises. Capital requirements for alternative manure storage structures are summarized. Finally, an assessment of the economic value of manure from alternative disposal systems is presented.

CAPITAL REQUIREMENTS

Capital investments are estimated for dairy, beef and swine waste disposal systems. The systems and structures presented are only a few of the many available to producers. These investment estimates may give producers some notion of the magnitude of the capital investments for common systems and structures. Costs of manure storage structures are presented in a separate sub-section following swine system costs.

Dairy Systems

Investments are estimated for three waste disposal and runoff control systems for dairy and are shown in Table 5. It is estimated that these three housing, waste disposal and runoff control systems are used on about two-thirds of Ohio's dairy farms with 30 or more cows.

Open lot, free stall housing systems are the most common systems in Ohio. Generally, this system is one of high labor and relatively low capital requirements. Cattle are housed in free stall areas with access to an outside lot. Manure is scraped from the lot surface and

Table 5: Estimated Capital Investment Per Head for Three Dairy Waste Disposal Systems, Three Herd Sizes, 1980 Price Levels

Housing Type	Dairy Herd Size (Head)		
	50-74	75-99	100+
	Capital Investment Per Head ($)		
Open lot, free stall housing, scraper loader system, grass filter runoff control[1]	300	260	150
Enclosed cold housing, free stalls, scraper/loader system[2]	270	220	180
Enclosed cold housing, free stalls, liquid system[3]	450	400	290

[1] Capital investments include purchase price of manure spreader, scraper and loader, tractor and grass filter strip.
[2] Capital investments include purchase price of manure spreader, scraper, loader and tractor.
[3] Capital investments include purchase price of manure spreader, scraper and loader, tractor, liquid spreader, storage tank, pump and agitator.

free stall housing and is either spread on fields immediately or stored to be spread at a later date. Runoff may be controlled by either a settling basin and a retention pond system or a grass filter area. Estimates in Table 5 are based on a grass filter runoff control system with minimal manure storage facilities and regular spreading of wastes to fields.

Enclosed housing with free stalls and a scraper loader is also a common system. In the enclosed housing system, the animals have minimal access to exposed lots. As a result of this concentrated area, equipment and labor requirements are slightly less.

Enclosed housing with free stalls and a liquid system is seen on larger dairy farms. During periods when fields are not suited for spreading, manure is scraped or pumped into storage. Liquid spreaders are used to spread the stored manure. When field conditions are suitable, manure may be loaded and hauled directly from the lots. Generally, this system requires the most capital and least labor of the three systems. The liquid storage tank and enclosed housing reduce manure runoff to near zero levels, and the system allows for a wide range of flexibility in managing the wastes.

Beef Systems

Capital investments estimated for three beef waste disposal and runoff control systems are shown in Table 6. The first system, an unpaved drylot housing system, allows 25 square feet of concrete floor per head in covered housing with 150 square feet per head of unpaved outside lot. Manure is scraped from the facility and spread immediately or stored to be spread at a later date. Runoff control is by means of a runoff retention facility or grass filter area (see section on Runoff Control). Labor requirements are relatively large due to the large feedlot area and the need for periodic scraping and hauling. In addition, the large feedlot area requires a relatively large runoff retention facility or grass filter area to accommodate the runoff. Cost estimates are based on using the grass filter as the method of runoff control.

The second beef housing system is a paved, drylot system with 25 square feet of covered housing per head and 30 square feet of paved outside lot per head. The waste disposal equipment required with this system is nearly the same as the unpaved lot system; however, slightly less labor is required due to the reduced lot area. Cattle are generally cleaner on this type of lot and scraping is less of a problem than with unpaved lot surfaces. Runoff control is accomplished by a grass filter at the edge of the feedlot or by a runoff retention facility. Capital investment in the paved drylot system is slightly greater than the unpaved lot system due to the increased capital investment in the concrete lot surface.

In the confined slatted floor system, each animal is allocated 30 square feet of enclosed area. The pit beneath the slats is emptied periodically with a liquid spreader. Labor requirements for waste disposal are less than either the paved drylot or unpaved drylot systems. Capital investments are substantially higher in

Table 6: Estimated Capital Investment per Head for Three Beef Waste Disposal Systems, Three Herd Sizes, 1980 Price Levels

Housing Type	Beef Feedlot Capacity (Head)		
	100	400	700
	Capital Investment Per Head ($)		
Unpaved drylot, housing scraper loader system, grass filter runoff control[1]	150	70	60
Paved drylot, housing, scraper/loader system, grass filter runoff control[1]	155	75	65
Confined slatted floor, liquid system[2]	300	180	165

[1] Capital investments include purchase price of manure spreader, scraper and loader, tractor and grass filter and exposed portion of the feedlot.
[2] Capital investments include purchase price of liquid spreader, pump, tractor, slatted floor and pit. Investment in slatted floor and pit is the difference between the investment in the slatted floor and pit and the solid floor required in the other two housing types.

Table 7: Estimated Capital Investment Per Head of Annual Swine Production for Two Swine Waste Disposal Systems, Three Herd Sizes, 1980 Price Levels

Housing Type	Annual Swine Production (Head) 500	1500	2500
	Capital Investment Per Head Annual Production ($)		
Enclosed, partially slatted floor, liquid system[1]	42	27	25
Open front, paved lot, scraper/loader system, grass filter runoff control[2]	36	21	18

[1] Investment includes purchase price of liquid spreader, pump, tractor and partially slatted floor and pit. Investment in the floor is the difference between the total investment in the partially slatted floor and pit and the solid floor required in the open lot system.
[2] Investment is purchase price of spreader, loader, tractor, exposed feedlot surface and grass filter.

the confined system; however, feed efficiency generally is improved as compared to the other two beef housing systems.

Swine Systems

The capital investments for two swine waste disposal and runoff control systems are shown in Table 7. These two systems account for about 50 percent of the hog production systems in the Corn Belt and Lake States.

The enclosed, partially slatted facilities allow an average of seven sq. ft. per head. Approximately half the floor is slatted with the remainder solid. Manure is stored in the pit. Labor requirements are less under this system than under the open lot system; however, capital investment is higher than under the open lot system.

About 7 square feet per head of sheltered space plus 7 square feet per head of paved lot are allowed in the open front facility. Manure is scraped regularly from the lot and is either spread immediately or stored for spreading at a later date. Runoff can be controlled by a grass filter, or by a runoff retention facility.

Manure Storage Structures

Manure storage has and will become a more important part of waste management as producers planning for timely application take into consideration plant growth, labor and machine availability, pollution control and nutrient conservation. Capital requirements for constructing seven different types of manure structures for dairy, beef and swine enterprises are presented in Tables 8, 9 and 10. An important factor in selecting the type of manure storage is the potential for odor nuisance. This factor may override cost considerations.

LABOR REQUIREMENTS

Labor requirements for alternative livestock waste disposal systems vary widely due to livestock numbers, type of waste disposal system, location of feedlot, season of the year and the level of management. This variability is reflected in Table 11, which estimates the annual hours of labor required for waste disposal activities on farms with various livestock enterprises, housing systems and enterprise size. Research data used to compile these labor estimates come from a variety of sources, including surveys and best estimates of Extension personnel. These estimates should be used only as approximations of labor requirements of actual systems.

The level of management required varies among waste disposal systems. Generally, the more confined the system, the more management ability is required to solve disease, feeding and equipment problems that occur with the more intensified systems. The farmer contemplating a change from an open lot to a confined system should realize that his management problems are not reduced by the confinement system. While his

Table 8: Estimated Investment Cost of Manure Storage for 100 Dairy Cows (Average Weight 1400 pounds, 1980 Price Level)

Type of Structure	Months of Storage 3	6	12
Solid Handling[1]			
Plank wall — concrete floor	$ 8,000	$15,000	$ ——
Concrete wall — concrete floor	9,000	16,000	——
Liquid Handling[2]			
Above Ground			
Concrete tank — round, no cover	15,000	24,000	——
Metal tank — round, no cover	20,000	27,000	——
Below Ground			
Concrete pit — no cover, slats	25,000	40,000	——
Concrete tank — covered	37,000	54,000	——
Earthen basin	——	20,000c	34,000c

[1] 1.85 cu ft/cow/day required
[2] 2.5 cu ft/cow/day required (includes milking parlor wastewater)
[3] This cost is for moving earth equal to total storage volume. Depending on manure system and topography, this cost can be reduced 25 to 50% when the cut and fill is balanced.

Table 9: Estimated Investment Cost of Manure Storage for 400 Head Beef Feedlot (Average Weight 750 Pounds, 1980 Price Levels)

Type of Structure	Months of Storage[1]		
	3	6	12
Solid Handling			
Plank wall — concrete floor	$10,000	$18,000	$ ——
Concrete wall — concrete floor	11,000	19,000	——
Liquid Handling			
Above Ground			
Concrete tank — round, no cover	18,000	28,000	——
Metal tank — round, no cover	24,000	32,000	——
Below Ground			
Concrete pit — under slats	30,000	48,000	——
Concrete tank — covered	44,000	64,000	——
Earthen basin	——	24,000[2]	40,000[2]

[1] 0 75 cu ft/head/day required

[2] This cost is for moving earth equal to total storage volume Depending on manure system and topography, this cost can be reduced 25 to 50% when the cut and fill are balanced

Table 10: Estimated Investment Cost of Manure Storage for 1000 Head Hog Feedlot (Average Weight 150 Pounds, 1980 Price Level)

Type of Structure	Months of Storage[1]		
	3	6	12
Solid Handling			
Plank wall — concrete floor	$ 5,000	$10,000	$ ——
Concrete wall — concrete floor	6,000	11,000	——
Liquid Handling			
Above Ground			
Concrete tank — round, no cover	10,000	15,000	——
Metal tank — round, no cover	13,000	17,000	——
Below Ground			
Concrete pit — no cover, slats	16,000	26,000	——
Concrete tank — covered	24,000	34,000	——
Earthen basin	——	13,000[2]	21,000[2]

[1] 0.16 cu ft/head/day required.

[2] This cost is for moving earth equal to total storage volume. Depending on manure system and topography, this cost can be reduced 25 to 50% when the cut and fill are balanced.

Table 11: Estimated Hours of Annual Labor Required in Waste Disposal Systems for Dairy, Beef and Swine at Three Size Levels

	Dairy Herd Size (Head)		
Dairy Systems	**50-74**	**75-99**	**100**
Open lot, free stall housing, scraper loader system	320 hrs	420 hrs	510 hrs
Enclosed cold housing, free stalls, scraper loader system	300	410	500
Enclosed cold housing, free stall, liquid system	240	340	413
	Beef Feedlot Capacity (Head)		
Beef Systems	**100**	**400**	**700**
Drylot, unpaved housing	340 hrs	500 hrs	680 hrs
Drylot, paved housing	280	420	560
Confined, slatted floor housing	220	340	450
	Swine Annual Production (Head)		
Swine Systems	**500**	**1,500**	**2,500**
Totally enclosed, partially slatted floor	150 hrs	220 hrs	290 hrs
Open Lot	180	270	350

Table 14: Annual Value of Manure from Dairy, Beef and Swine as a Substitute for Commercial Fertilizer Under Five Waste Disposal Systems, 1980 Price Levels[1]

	Dairy (1400 lb. Animal)	Beef (750 lb. Animal)	Swine (150 lb. Animal)
Bedded building, solid spreading	$67	$37	$9.80
Open lot, solid storage, surface spreading	$48	$26	$7.00
Aerobic lagoon, irrigation or liquid spreading	[2]	[2]	$9.50
Deep pit storage, liquid spreading	$67	$37	$9.80
Anerobic lagoon, irrigation or liquid spreading	$30	$17	$4.50

[1] Price assumptions for nutrients: N = $0.25/lb, P_2O_5 = $0.22/lb, K_2O = $0.10/lb Losses of N, P and K per Table 4 are included.
[2] Normally not used for this type of livestock

hours of labor may decline, more managerial effort is required with the confinement system.

FEED EFFICIENCY

Research data indicate that the type of housing and waste disposal system has an effect on the rates of gain and feed fed per day for swine and beef. Table 12 shows the average daily gain and feed fed per day in different types of housing and waste disposal systems. Typically, cattle show larger daily gains with the enclosed systems and are more efficient in the use of the feed.

Swine rates of gain and feed fed per day are also affected by housing types, as shown in Table 13. Generally, enclosed housing requires approximately the same number of days to feed swine from 30 pounds to 240 pounds in weight, but requires less feed to accomplish these gains.

Table 12: Average Daily Gain and Feed Fed Per Day for Feeder Cattle in Three Housing Systems[1]

Housing System	Average Daily Gain[2]	Feed/Day, Pounds Corn	Feed/Day, Pounds Silage
Outside lot	1.80	6.4	32.8
Partially covered lot	2.00	6.4	31.6
100% covered lot	2.05	6.4	31.6

[1] Data from J. R. Black and H. D. Ritchie, "Average Daily Gain and Daily Dry Matter Intake of Various Kinds of Cattle Fed Three Different Rations Under Several Environmental Situations", Staff Paper 1973-1, Department of Ag. Econ., Michigan State University. 1973.
[2] Feeding weights are 450-1050 pounds.

VALUE OF MANURE

Manure has value as a substitute for commercial fertilizer; however, the price tag to place on the manure is difficult to calculate due to the variability of the nutrient content in manure. The nutrient value depends on the type of animal, weight of animal, ration, housing system, bedding material used, storage system, time of the year in which the waste is spread and commercial fertilizer prices. Table 14 approximates the annual value of fertilizer nutrients for dairy, swine and beef under alternative housing and disposal systems.

Differences in fertilizer values between housing and disposal systems in Table 14 are explained by the differences in the percent of nitrogen remaining after storage and spreading under various systems. Systems that allow for solid spreading generally have a higher percentage of nitrogen remaining after storage and spreading than those systems with liquid spreading.

It should be noted that the data in Table 14 refer to the average annual value of manure per head. Thus, if a farmer had a confined hog facility that housed an average of 500 head in the facility throughout the year and the swine averaged 150 pounds per head, the value of the manure would be $4,900 under current fertilizer prices ($9.80 per head from Table 14 times 500 head).

Table 13: Average Daily Gain and Feed Fed Per Day for Swine in Three Housing Systems[1]

Housing System	Average Daily Gain, Pounds	Average Daily Feed, Pounds
	30-105 Pound Hogs	
Enclosed, heated	1.76	3.33
Enclosed, unheated	1.76	3.61
Open front	1.65	3.96
	105-240 Pound Hogs	
Enclosed, heated	1.80	6.36
Enclosed, unheated	1.80	6.31
Open front	2.00	7.37

[1] Data from A. H. Jensen, B. G. Harmon, G. R. Carlisle and A. J. Muehling, "Management and Housing for Confinement Swine Production", Circular 1964, University of Illinois, 1972.

FEEDLOT RUNOFF CONTROL

Livestock feedlots are typically located to utilize natural surface drainage conditions. These conditions necessitate control facilities to intercept and store or treat surface runoff so manure-contaminated waters are prevented from entering the waters of the state. Intercepted runoff is generally applied to agricultural lands to provide storage volume and to allow for utilization of manure nutrients. It is fortunate that many animal facilities are partially or completely under roof. This reduces runoff pollution. When it is not practical to cover existing feedlots, alternative measures are needed to control feedlot runoff. The major components of a runoff control system are shown in Figure 16.

DIVERSION

All clean surface water is diverted away from the feedlot. All roofs that would contribute to runoff from the feedlot should have gutters, downspouts and outlets that discharge the roof water away from the feedlot. A 25 year, 24 hour storm should be used in the design of the diversion system.

COLLECTION

The runoff from the feedlots will need to be collected and directed to the holding pond or settling basin. This can be done by diversions, curbs, gutters, by lot paving and, in some cases, by pumping.

HOLDING POND

A holding pond, basin or tank may be used to store the total feedlot runoff until it can be applied to the land. The storage volume should be adequate to hold the runoff expected for the storage period plus 25 percent additional storage for emergency situations. The holding pond must be emptied on schedule as set out in a waste management plan. The deposition of solids in a holding pond can be reduced by the use of a settling basin.

SETTLING BASIN

A settling basin or channel provides an area for settling out the settleable solids, which then can be handled in a solid form. The settling basin functions to keep solids out of an infiltration area or a holding pond.

To provide settling, the ponded surface area should be five percent of the feedlot area. This area includes the feedlot plus any roof or land area that adds runoff. To prevent scouring of the settled solids out of the settling basin, the liquid cross-sectional area should be five percent of the ponded surface area. For example, a 10,000 square feet feedlot would need a settling area of 500 square feet of liquid surface and 25 square feet of liquid cross-section (See Figure 17).

In addition to the above liquid surface and cross-section, the settling basin needs to have storage for solids. For a paved lot, provide storage for the manure likely to be washed off the lot between scrapings. The maximum amount likely to be washed off is one inch of solids over the lot area. This would require 20 inches of storage depth when the settling area is five percent of the lot area. For dirt lots, allow for a maximum amount of ½-inch of solids eroded from the lot, which would require a minimum of 10 inches of depth in the settling basin for solids.

The settling basin must be properly managed. The basin must be emptied soon after each runoff event to reduce odors and restore the basin capacity. From past experience and research, it has been found that continual drainage or seepage from the settling basin can be harmful to a vegetated filter. When the discharge is to a vegetated filter strip, the release of the liquid should be done manually. It is recommended that this be done with a plank or stop gate arrangement. The planks are to be removed at intervals that do not cause scouring of the settled solids (See Figure 18). It is recommended that 2 inch x 4 inch or 2 inch x 6 inch planks be used (but no larger than 2 inches x 6 inches). The stop gate should be a minimum of 18 inches in length. Replace the planks immediately after draining the liquid to be ready for the next storm.

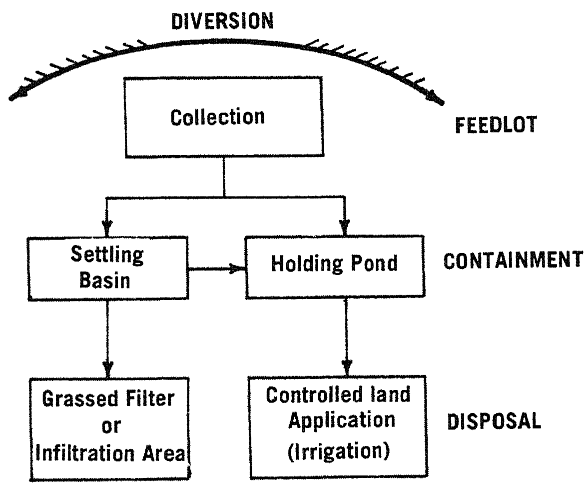

Fig. 16: Components in Runoff Control System.

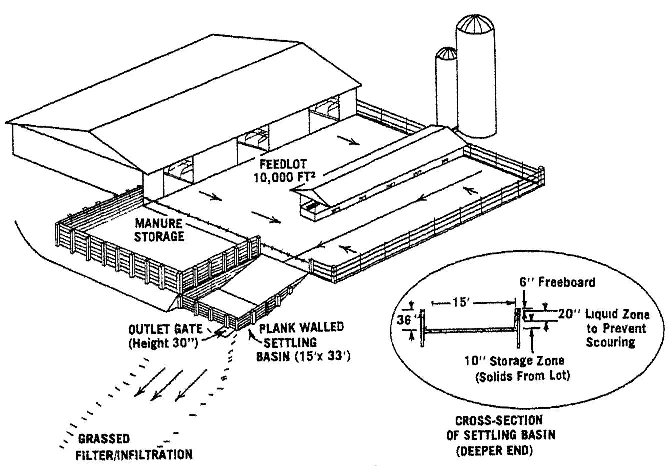

Fig. 17: Illustration of Runoff Control System.

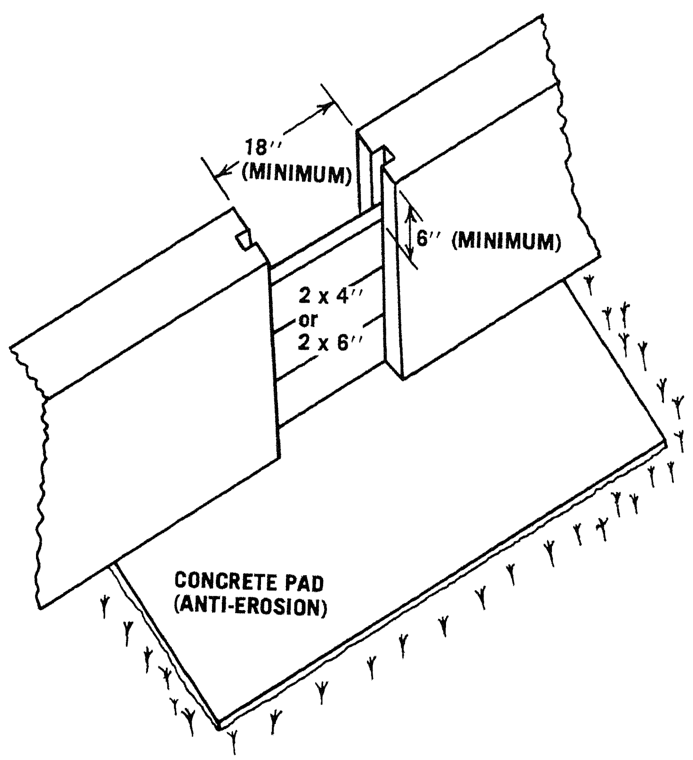

Fig. 18: Plank (stop) gate at outlet of settling basin.

To make scraping more practical, liquid and solid depths can be reduced by proportionately increasing the surface area above the five percent basis. It is often practical to provide the settling basin on the feedlot by placing a curb along the low part of the lot. The solids trapped by the temporary ponding can be removed after draining off the water, when the lot is scraped.

It is important that the settling basin or channel is shaped and located so that it can be easily managed and maintained.

DISPOSAL

For **holding ponds**, it is usually more economical to use irrigation equipment to transport the liquid to the disposal area. If the manure is handled as a liquid, it may be feasible to use the same disposal equipment for the contained runoff. Follow the emptying schedule laid out in the waste management plan developed for your system.

A **grass filter/infiltration area** is effective in treating feedlot runoff after the solids have been settled out. The grass filter must be designed, constructed, vegetated and adequately maintained for it to be effective.

In order to meet Ohio water pollution abatement standards for feedlot runoff control, the filter/infiltration area must be constructed and maintained in accordance with the criteria in this section. A construction plan must be prepared for each site. Grading or land forming of the filter area must not be done when the soil is wet so that the soil infiltration capacity will not be decreased. Other surface water should be diverted out of the filter area. Where the grass filter is designed on flat topography, or on heavy soils, it is usually necessary to install a subsurface drain along the grass filter to assure quality vegetation and trafficability for periodic mowing. Livestock should be excluded from the grass filter.

The success of the filter largely depends on the establishment and maintenance of a good stand of vegetation. In planning the facility, provisions must be made to have an established stand of vegetation before allowing lot runoff on the filter. Fescue and reed canarygrass have proven to be acceptable. The natural habitat for reed canarygrass is a poorly drained, wet area; nevertheless, it is also one of the more drouth-tolerant grasses and can utilize high fertility.

Ponding and the buildup of solids at the beginning of the filter can be minimized by using a slope of 2 percent or more for the first 50 feet. Slopes can be decreased to 0.5 percent for the remainder of the filter area. On steep topography, the filter area should be a gradient terrace with a slope that will not allow erosion to occur.

The bottom of the channel should be flat in cross-section. It should have a minimum bottom width of 8 feet and a maximum of 20 feet. If wider channels are needed, meandering and channelization can be controlled with low dividing ridges. The minimum ratio of the filter area to the feedlot area for swine should be 1:1. For all other livestock, it should be 0.3:1, unless special designs are needed. The length can be straight or it can take on a switchback shape, depending on the area where the filter is located. The length of the channel can be reduced by decreasing the lot area, diverting lot and roof water, decreasing the amount of manure exposed to rain or by increasing the width of the grass filter.

The selection of the final design of the grass filter takes into consideration the topography and area available, number and size of animals, lot size and lot management procedures.

The equation for calculating the length (L) and the width (W) is:

$$W/A = (S_f \times C_f /L)^{2.5} \times (0.0351/n)^{1.5}$$

- A =Areas of the feedlot and other sources of runoff through the lot (sq. ft.)
- C_f =Concentration factor = MxDxPxN/A
- M =The proportion of the manure deposited on the outside lot subject to runoff (%)
- D =Four plus the number of days the lot is not scraped. (For all scraping intervals greater than six days, use D = 10)
- P =The average weight of the animals in pounds
- N =The number of animals
- S_f =The % slope of the grass filter raised to the 0.3 power
- n ="D" retardance in the Engineering Field Manual, SCS, USDA, but not greater than 0.3

Figure 19 was developed to solve the above equation by setting the time of travel (min.) to be 0.5 x C_f when the velocity (ft./sec.) times flow depth (ft.) is equal to A/4000 x W). Table 15 calculates the S_f, which is the percent of slope of the grass filter to the 0.3 power.

Use of Figure 19 (page 24) and Table 15 is illustrated as follows:

Table 15: Grass Filter Slope Factor, S_f

% Slope	.5	1.	2.	4.	8.	16.
S_f	.8	1.	1.2	1.5	1.9	2.3

For slopes not listed, use the next higher value.

Example 1. Determining the grass filter width for a selected filter length.

Given: 200 beef animals weighing 800 pounds on an 8000 sq. ft. feedlot with half the manure outside, scraped weekly. Slope of filter area is 2 percent with a selected length of 400 feet.

$$S_f \times C_f = (S_f) \times (M \times D \times P \times N/A)$$
$$= (1.2) \times (0.5 \times 10 \times 800 \times 200/8000)$$
$$S_f \times C_f = 120$$

$$1000/A \times W = 2 \text{ (from Figure 19)}$$
$$W = 2 \times A/1000$$
$$= 2 \times 8000/1000$$
$$W = 16 \text{ ft.}$$

Example 2. Determining the grass filter length for a selected width.

Given: 100 dairy cows weighing 1200 pounds on a 5000 sq. ft. feedlot. Half the manure is outside and the lot is scraped daily. The selected grass filter width is 8 feet and the ground slope is 1 percent.

$$S_f \times C_f = (1.0) \times (0.5 \times 4 \times 1200 \times 100/5000)$$
$$S_f \times C_f = 48$$

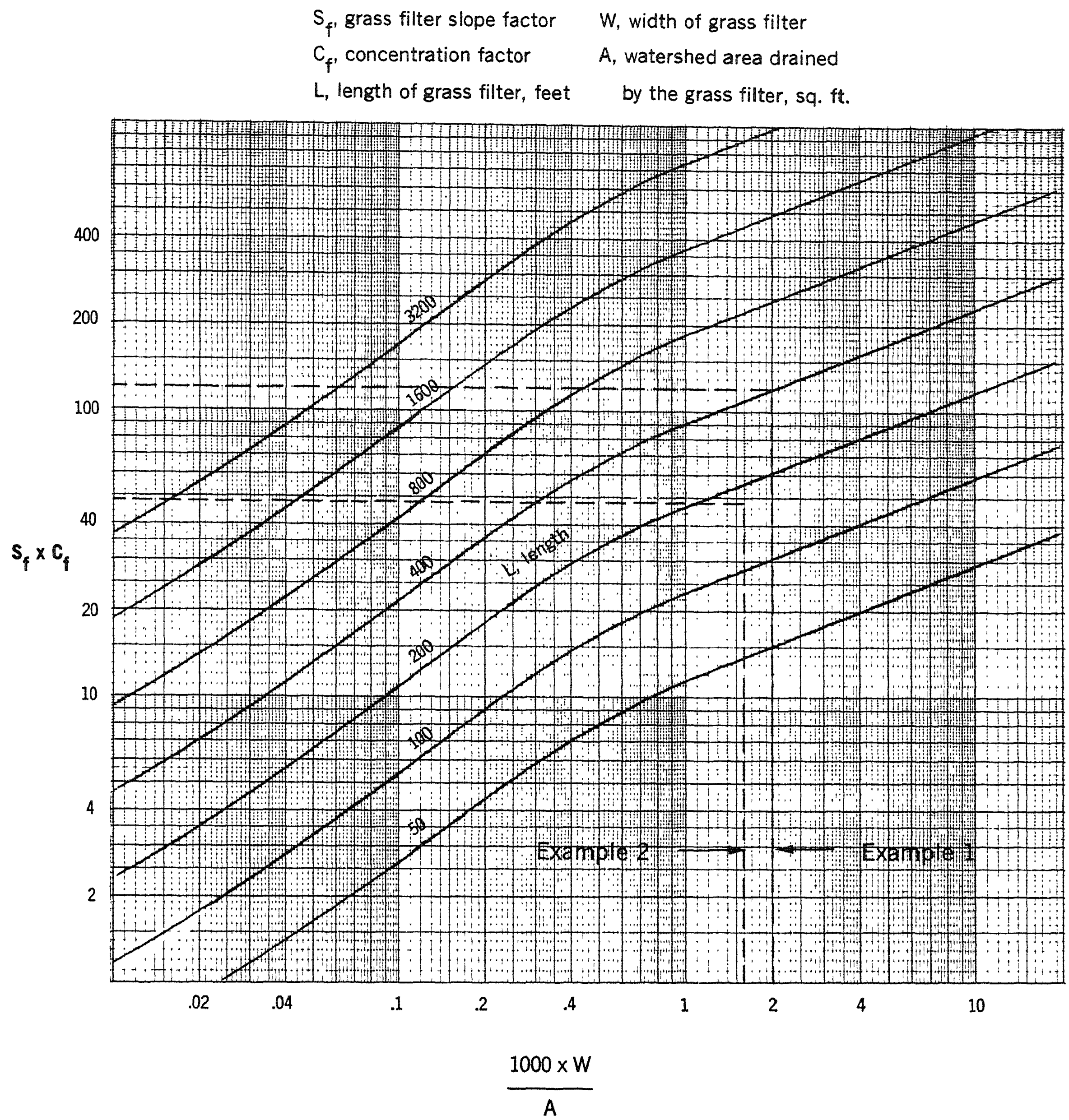

Fig. 19: Curves for determining grass filter area (length or width).

1000 x W/A = 1000 x 8/5000
1000 x W/A = 1.6

From Figure 19, L = 175 feet

To keep solids from building up at the entrance, increase the slope to 2 percent for the first 50 feet.

Vegetation must be mowed regularly to maintain a dense sod. Grass clippings must be removed from the channel. Refrain from late fall mowing so the grass has a chance to go into winter with a good cover.

Under good maintenance, a buildup of solids can still be expected on the upper end of the filter. Removal of solids and revegetation should be done every three to five years as normal maintenance.

The daily discharge of milking facility wastewater into the grass filter is not permissible. Daily discharges will result in a wet area that cannot be managed from the standpoint of mowing, grass removal and insect control.

Special conditions: There may be locations where it is desirable to direct the feedlot runoff to cropland. In any situation, the runoff should go through some grassed area to filter out solids before being directed to cropland. For the cropland to serve as an infiltration area, three factors must be considered: (1) soil infiltration rate, (2) slope of cropland and (3) distance to a stream. The disposal area should also be checked for possible surface entry into bedrock and for surface inlets as part of an underground drainage system. Each site must be judged on its own needs and a design selected that will provide the needed protection of surface and groundwater.

TREATMENT UNITS

Manures are treated for the purpose of abating pollution or nuisances and for obtaining a useful byproduct for recycling. Two major areas of treatment will be considered: separation of the liquid from the solid portion of the manure and biological treatment in lagoons. A treatment unit is only one part of a total waste management system. The total system must be properly designed and managed.

LIQUID-SOLID SEPARATION

Separation may be done by settling, screening, pressing, centrifuging or dehydrating. Mechanical separation equipment and the flow of liquids and solids are depicted in Figure 20.

Purposes of liquid-solid separation include:

- Particles (solids) may be reused, e.g. bedding.
- Solids may be treated (processed) and then fed.
- Biological treatment units function with less trouble when roughage, hair, feathers, etc. are removed.
- Irrigation of slurry will be facilitated by removal of course or fibrous solids.

Gravity settling of solids from a dilute slurry occurs when the flow velocity is reduced. In those cases where the settled solids are not dewatered, a liquid handling system for the slurry will be needed. Slurries will occur in settling the following: milking parlor wastewater, hog lot runoff and manure flushed from hog buildings. Solids settled from cattle feedlot runoff normally can be handled in a solid form. The separated liquid fraction will have too much organic matter for disposal into leach beds, field tiles, ditches or streams. Disposal of liquids by controlled application on cropland or further biological treatment are acceptable methods of handling the liquid fraction. For design information on runoff control, see the section on Feedlot Runoff Control and MWPS 18.

Mechanical separation systems must provide for handling and disposal of both the liquid and solids fraction. Advantages of mechanical separation include: solids are more stable and cause fewer odor problems, solids may be reused and liquid fractions can be pumped easily. The cost of mechanical separation will need to be weighed against the value of the separated products or the improved handling characteristic. Mechanical separation systems are being marketed commercially with application to refeeding solids or using solids as a free stall bedding material.

Evaporation of water may be done in a drying bed or by using a heated dehydrator. Drying beds are not common in Ohio because of moderately high rainfall rate. Dehydrating manure is not too practical because of the high cost of energy.

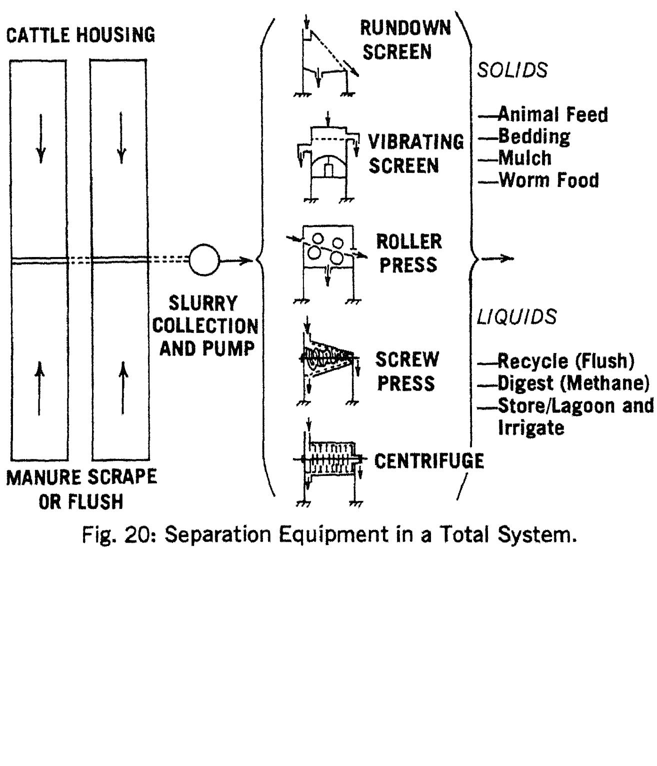

Fig. 20: Separation Equipment in a Total System.

BIOLOGICAL TREATMENT

Composting is an aerobic treatment process that can be used with manure in the solid form. Manures and bedding with a moisture content of 50 to 70 percent will compost readily. Aeration to provide needed oxygen can be supplied by turning windrowed manure piles or by forced aeration of composting manure. Heat is generated in the composting process, and temperatures of 160°F should be reached. These temperatures will kill pathogens and weed seeds. The composting process will take from 10 to 30 days or longer. Advantages of composting are:

- A stable organic material without offensive odors.
- A product free from weed seeds and pathogens.
- A product with about 0.5 percent nitrogen, 0.4 percent phosphorus and 0.2 percent potassium useful as a soil conditioner and garden fertilizer.

Composting of livestock manures is not commonly done because of cost and the management and marketing requirements. Also, the ease of land spreading manure with greater nitrogen recovery does not make composting practical for most livestock operations. Composting may be a good waste management alternative for large confined livestock operations with little land for manure application.

Lagoon treatment of manure slurries is done with one of two systems: anaerobic or aerobic (either naturally aerated or mechanically aerated).

Anaerobic lagoon design in Ohio is based on organic matter (volatile solids) loading for a unit volume. The required minimum volume for three zones in Ohio are listed in Table 16. The three zones, based on mean January temperature, are shown in Figure 21.

Total lagoon volume must include five components as follows:

1. Minimum design volume (MDV) per table. Maintained at all times in lagoon.
2. Dilution volume (DV) = ⅓ of MDV. Includes collected runoff, net rainfall, fresh water, etc. in the DV. Dispose DV annually on cropland (usually irrigated).
3. Annual manure and wastewater volume. Dispose annually on cropland.
4. Volume for 25-yr., 24-hr. storm.
5. Freeboard (minimum of 1 ft.).

The depth of anaerobic lagoons can vary from a minimum of 8 to 10 feet up to a maximum of about 16 feet. Deeper lagoons will not warm to the bottom during spring warm-up period and have a potential for more odor.

The key to well functioning anaerobic lagoons is **man-**

Table 16: Required Minimum Design Volume (MDV) for Anaerobic Lagoons[1]

Species	lb VS/day per lb Live Weight	MDV (ft³/lb live weight)[2] Zone 1	Zone 2	Zone 3
Dairy Cattle	0.0086	3.4	2.9	2.5
Beef Cattle	0.0059	2.4	2.0	1.7
Swine	0.0048	1.9	1.6	1.4
Poultry (layers)	0.0094	3.8	3.1	2.7
Sheep	0.0085	3.4	2.8	2.4
Horses	0.0075	3.0	2.5	2.2

[1] The design loadings are conservative to provide reasonable odor control. With good isolation of lagoon, more than 2000 ft. to neighbor(s) or 2500 ft. to built-up area, the MDV can be decreased 25%, e.g. beef cattle in Zone 2 — the MDV can be decreased from 2.0 to 1.5 ft³/lb live weight.

[2] Design criteria as follows: Zone 1 — 2.5 lbs VS/day per 1000 ft³
Zone 2 — 3.0 lbs VS/day per 1000 ft³
Zone 3 — 3.5 lbs VS/day per 1000 ft³

agement. The following items are a summary of management criteria:

1. Start-up of lagoons is critical. If manure loading begins in the fall or winter, the MDV must be filled first with water from surface runoff, stream water, well water, etc. If loading begins in the spring or summer, the MDV must be filled half full with water before loading with manure. Failure to do this has resulted in odor problems.
2. Manure and wastewater should be loaded on a continuous basis, e.g. daily preferred, or every second or third day. Slug loading a large quantity of manure, e.g. pumping from a large pit beneath a slatted floor, can cause odor problems. The method of overflowing pit wastewater (trickle tube) without solids hinders the seasonal working of the lagoon by reducing natural mixing.
3. The dilution volume (DV) and the annual manure and wastewater volume must be spread onto land every year. Regular yearly dilution of lagoon contents is essential for odor control. If dilution is not provided, dissolved salts build up in the lagoon water and a balanced biological decomposition is hindered. Odors can result. Because of the dilute nature of lagoon water, irrigation is the common method for disposal of effluent and it can be spread on growing crops, e.g. corn and alfalfa.
   A second purpose for diluting the lagoon with water is so that purple (reddish) sulfur bacteria will grow. These sulfur bacteria are photosynthetic and sunlight must be able to penetrate the lagoon water to promote their growth. These bacteria oxidize reduced forms of sulfur such as hydrogen sulfide to sulfur or sulfate, and thus possess the ability to reduce or eliminate sulfur related odors within an anaerobic lagoon.
4. When irrigating lagoon water, the suction inlet should be near the bottom. This will have two benefits: the solids content of the lagoon will be lowered and more nutrients will be moved to the crops. Sludge build-up can also be avoided. If a two-stage lagoon is used, it is recommended that the wastewater to be used for irrigation be taken from the first lagoon, and then recharge the first lagoon to its operating depth from the second lagoon.
5. A well-functioning lagoon will have a neutral pH (7.0 to 8.0). If the pH drops below 6.7, hydrated lime or caustic soda (lye) should be added daily at a rate of one pound per 1,000 cubic feet of lagoon volume until the pH rises above 7.0 and the odors diminish. Addition of hydrated lime or lye to new lagoons may be needed to provide buffering capacity until the lagoon becomes biologically stable.

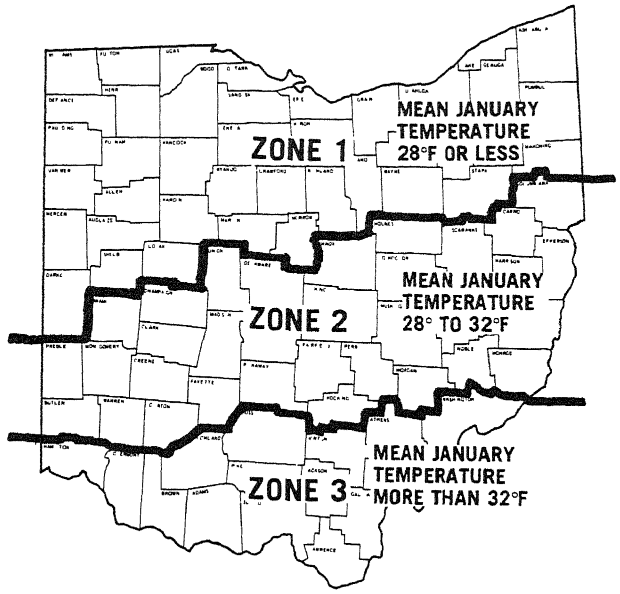

Fig. 21: Zones in Ohio for designing anaerobic lagoons.

For guidelines on disposal of lagoon water, the reader is referred to the sections on Land Application and Irrigation.

Aerobic lagoons may be one of two types: naturally aerated or mechanically aerated. Oxygen is provided through the lagoon surface for naturally aerated lagoons. Therefore, design is based on surface area. Table 17 gives the required surface area for the three zones in Ohio. The depth of the water should be three to five feet to allow light penetration and to minimize the growth of aquatic plants on the bottom. The total volume of the lagoon should include, besides the design area/depth, a storage or holding capacity for one year. This holding capacity is based on annual waste volume plus dilution volume of 100 ft³ per daily pound of BOD_5. Direct discharge to streams is not allowed unless additional treatment is given to meet effluent standards.

Table 17: Required Surface Area of Aerobic Lagoon (Natural Aeration)

Species	lb. BOD_5/Day/ lb. Live Weight	Lagoon Surface Area (ft²/lb live weight) Zone 1	Zone 2	Zone 3
Dairy Cattle	0.0017	3.0	2.5	2.1
Beef Cattle	0.0016	2.8	2.3	2.0
Swine	0.0020	3.5	2.9	2.5
Poultry (layers)	0.0035	6.1	5.1	4.4
Sheep	0.0009	1.6	1.3	1.1
Horses	0.0010	1.7	1.5	1.2

Design criteria as follows:
Zone 1 — 25 lbs BOD/day per acre; Zone 2 — 30 lb. BOD/day per acre;
Zone 3 — 35 lb. BOD/day per acre.

The minimum design volumes for mechanically aerated lagoons is given in Table 18. Mechanical aeration can be provided by floating pump-type aerators, floating air induction aerators or submerged diffusion (bubbler) aerators. Pump type aerators will freeze up in winter and are not recommended unless they can be shut off during freezing conditions. Oxygenation capacity of equipment should be obtained from the manufacturer. For complete aerobic treatment, provide oxygenation capacity at twice the daily BOD_5 loading.

Aeration for odor control may be provided at an oxygenation capacity of 0.5 times the daily BOD_5 loading. In this case, the lagoon is operating facultatively, lower portion anaerobic and surface layer aerobic.

Aeration equipment should provide aerated liquid for the total lagoon surface. For pump type aerators, this requires about 1 horsepower (hp) per 1000 ft^2. Induction or diffused (bubbler) aerators should provide air bubble release over the surface area or movement of water over entire surface area.

Total aerated lagoon volume has five components:
1. Minimum design volume per Table 18.
2. Dilution Volume = ½ of MDV. Includes collected runoff, net rainfall, fresh water, etc.
3. Annual manure and wastewater volume.
4. Volume for 25-yr., 25-hr. storm.
5. Freeboard (minimum of 1 ft.)

The minimum depth is controlled by the aeration device. The lagoon needs to be deep enough to prevent scouring of the bottom by floating aerators. For diffused (bubbler) aerators, a minimum depth of 12 to 15 feet is recommended to obtain good oxygenation capacity.

Table 18: Required Minimum Design Volume (MDV) for Mechanically Aerated Lagoon

Species	LB. BOD_5/lb Live Wt Each Day	MDV (Cubic feet/lb Live Wt)[1]
Dairy Cattle	.0017	0.34
Beef Cattle	.0016	0.32
Swine	.0020	0.40
Poultry (layers)	.0035	0.70
Sheep	.0009	0.18

[1] Based on 200 ft^3 of lagoon volume per daily lb. BOD_5

Management of aerobic lagoons is essential for satisfactory performance. Consider the following items:
1. Continuous, **daily** loading of manure or wastewater is required. No slug loading.
2. Annual dilution by irrigating dilution volume and manure/wastewater volume is essential. Two criteria for determining the proper degree of dilution are (1) that the electrical conductivity, a measure of dissolved salts, does not rise above 8000 mmhos/cm and (2) that the total solids remain below one percent. When irrigating, attempt to move as many solids as possible.
3. Follow a management plan with respect to amount and periods of aeration.

MILKING FACILITY WASTEWATER

Both the daily volume and the pollutional strength of milk center wastewater must be considered when designing milking facilities. Table 19 gives estimated daily quantities of wastewater. As herd sizes increase, less water is used per cow because the milking equipment washwater doesn't increase proportionately. These values are for facilities with parlors. It is assumed that holding areas are scraped and not washed down. Milking in stanchions produces less wastewater per day and the quantity of wastewater from milkrooms only will be ⅓ to ½ of the values given in Table 19.

Table 19: Estimated Quantities of Wastewater Discharged from Milking Centers

Cows Milked	Quantity
Up to 50	5 to 8 gal/cow-day
50 to 150	4 to 6 gal/cow-day
Over 150	2 to 4 gal/cow-day

COLLECTION OF WASTEWATER

The design of the wastewater collection system in the milking center is very important. Poor drain locations, improper floor slopes or inadequate piping, all lead to continual frustration for the operator. Floor slopes should be a minimum of 2 percent (¼ inch per foot). Drains should be recessed below floor level so that water and solids will easily enter the drain and not pond around it. Drains should be located in corners or at ends of gutters so that solids can be easily washed (hosed) into them. A water seal trap must be located in the drain pipe between the water disposal unit and the milking center to prevent gases from entering.

HUMAN WASTE HANDLING

Toilet water must be handled separately from milking center wastewater. Normally, a septic tank/leach bed system is used or the milking center toilet wastes may be piped to the waste system of a nearby house.

ALTERNATIVE HANDLING METHODS

The use of the conventional septic tank and leach bed for modern milking center wastewaters is no longer satisfactory for three reasons:
(1) Large herds (more wastewater)
(2) Use of sanitizers in cleaning the milking equipment may kill bacteria
(3) Manure solids washed from parlor floors will clog the leach bed

In areas where soils allow reasonable percolation, a modified septic tank system can work by using a presettling tank, a treatment tank, a dual leach bed and proper management. Solids will need to be pumped out of the presettling tank on a regular basis (monthly or bi-monthly) and from the treatment tank as needed. The effluent discharge will be alternated between the two leach beds on a monthly or bi-monthly basis.

A very acceptable and easy method of handling milking center wastewater is to put it into a liquid manure system. Addition of some water to dairy manure is needed if it is to be easily agitated and pumped. Including the milking center wastewater in liquid manure storage structures will provide the necessary dilution and solve the wastewater disposal problem. When designing liquid manure storage structures, extra volume must be provided for the wastewater.

Anaerobic (without air) and aerobic (with oxygen) lagoons have been used to handle milking center wastewaters. When properly designed and managed, little odor is generated. Seepage from earthen structures must not be allowed, so heavy (clay) soils are needed. Some form of effluent disposal on land is needed. Usually, the lagoon is designed to provide one year's storage.

An adaptation of the septic tank system is working well. Rather than using a leach bed, the effluent is periodically — every second to fifth day — discharged or pumped onto cropland, pasture or a designated grassed infiltration area. A pre-settling tank before the collection tank is needed to make this system function properly. Three methods can be used to discharge the wastewater: (1) Sprinkler irrigation, (2) controlled flood irrigation and (3) discharge into gradient infiltration terraces. Selection depends upon site constraints. Design for winter operation must include self draining pipes and winter nozzles if sprinkler irrigation is used. Where gravity discharge can be used, the second and third method can be adapted in an economical and environmentally sound way. The size and shape of the disposal area is affected by soil types, vegetation, topography, proximity to streams and quantity of wastewater. The vegetation on the disposal area must utilize the nutrients in the wastewater and be harvested. Cattle should not have continual access to disposal areas. Controlled grazing can be used when the disposal area is dry.

Whatever the disposal method being used, proper management is needed to prevent pollution and nuisances.

SILAGE DRAINAGE

About as many incidents of fish kill in Ohio are caused by silage drainage as by feedlot runoff or discharge of manure into streams. The sugars, proteins and acids in the silage drainage have a high BOD and are highly polluting to streams, besides being a significant loss of feed value.

Forage should be placed in the silo at the proper moisture content so as to avoid drainage from the silo. However, if drainage does occur, it should not be allowed to enter field tile, drainage ditches or streams. Collect the silage drainage and then spread it on cropland as one does liquid manure.

FLOODING OF FACILITIES

Livestock waste management facilities should not be located on flood plains unless protected from inundation or damage from a 25 yr., 24 hr. duration storm. Protective measures would need to be evaluated for each site. Measures to be considered would be: dikes, diversions, lot buildup, stream relocation or relocation of the facility.

Land application of animal waste should not be made on land that is subject to flooding, except during those times of the year when the possibility of flooding is nearly zero. The guidelines in the section on Land Application must be followed.

INSECT AND PEST CONTROL

Most insects reproduce in "'wastes." They may be a nuisance or be of economic concern due to transmission of disease, reduction in growth or production and adulterating food products. Of major concern are flies, mosquitoes and the rattailed maggot.

CONTROL OF FLIES IN AND AROUND LIVESTOCK FACILITIES

Good sanitation is the basis for all fly control programs. Nevertheless, it is often necessary to supplement sanitation practices with pesticides.

For successful fly control, organize a control program that best fits your farm. A single pesticidal product rarely gives the most effective and economical control. It is normally best to use a combination of pesticide formulations such as baits, residual sprays, space sprays, larvicides, etc during the fly season. Do not wait for heavy fly populations. It is much easier and less expensive to prevent heavy fly build up than to control heavy fly populations after build up. As fly populations begin to build up, take time to treat and **treat regularly.** Good **sanitation** is essential for insect control.

1. Remove all manure from livestock pens as frequently as possible. Calf and bull pens with animals in them require special attention. It is best to clean these pens once a week. A clean livestock barn has fewer fly problems.
2. Spread the manure thinly outdoors in order that fly eggs and larvae can be killed by drying.
3. Eliminate silage seepage areas, wet litter, manure stacks, old wet hay or straw bales and other organic matter accumulations that may attract flies anywhere on the farm. Wet feed remaining at the ends of managers will also provide a place for flies to lay eggs.
4. Provide proper drainage in barnyards. Use gravel and other fill to eliminate low spots in livestock yards.
5. Cut weeds and excessive plant growth around facilities where flies rest and breed.

Detailed information on chemical pesticides in the form of baits, space sprays, oral larvicides, hanging strips, manure drenches and residual sprays is found in Pesticides for Livestock and Farm Buildings, Bulletin 473 of The Ohio Cooperative Extension Service.

CONTROL OF FLIES IN MILKING FACILITIES

Extremely small amounts of pesticides can be detected in milk, and their presence is often illegal. Dairy farmers are cautioned not to use chemical pesticides in the milking facility unless they have been approved for use there. Check with federal or state sanitary codes regarding legality of insecticide baits, residual sprays or space sprays for milkrooms. For best control of flies, the following steps are recommended:

1. Follow steps discussed in preceding section to control flies in and around the dairy barn to reduce the number of flies entering the milking facility.
2. Use good, tight screens on doors and windows.
3. Use sticky fly strips where appropriate.
4. A positive pressure ventilation system with screened inlet(s) and screened louvered outlet(s) in the milkroom will help to keep flies out, particularly when doors are opened and closed.
5. Dichlorvas resin strips will give effective control if windows and doors are kept closed. Use strips in accordance with label directions. Replace strips when they become ineffective.
6. Use a spray of 0.06-0.1 percent pyrethins plus piperonyl butoxide oil-base fly sprays when the above strips do not give effective control. All milk equipment should be covered before spraying to prevent milk contamination.

MOSQUITO CONTROL

Effective mosquito control requires a well-planned program. Information on mosquito species and control procedures, including chemicals, is found in Bulletin 641, Mosquito Control, of The Ohio Cooperative Extension Service.

Water management to prevent mosquito breeding is essential for effective control. Eggs do not hatch unless they are in water. Locate standing water on premises and eliminate it if possible. Drain or fill stagnant water pools, puddles, ditches or swampy areas around the facility. Keep grass mowed around lagoons and other bodies of water.

CONTROL OF RATTAILED MAGGOTS

The larvae of the Syrphid fly live in highly polluted waters such as manure pits and lagoons. Maggots are able to live in the water, provided sufficient solids are present as food. The adult Syrphid flies resemble honey bees in appearance and are often seen "hovering" near the ground in the barnyard. These flies do not bite or sting. They are considered beneficial, as they are predaceous on aphids and other insects.

The maggots may become a nuisance when they migrate from the manure storage or lagoon. The maggots migrate to a drier place for pupation. They may migrate to feed bunks and contaminate the feed. They have accumulated in electrical boxes causing short circuits. They have congregated in stacks of egg cartons or in other places where they are not wanted.

Usually the occurrence of rattailed maggots is a result of poor management. When anaerobic lagoons are biologically active and do not have floating solids or scum, fly development is hindered. Banks of lagoons need to be mowed to prevent accumulation of solids at the water's edge . If a dry, floating crust forms on manure storage structures, fly development is hindered. Seepage spots associated with manure storage structures provide breeding area. The use of larvicides on manure and liquids in pits has been partially successful in controlling the maggots. Larvicides are listed in Pesticides for Livestock and Farm Buildings, Bulletin 473 of the Ohio Cooperative Extension Service.

PROFESSIONAL SERVICES AND PUBLICATIONS AVAILABLE

THE OHIO COOPERATIVE EXTENSION SERVICE

The purpose of the Ohio Cooperative Extension Service is to provide educational programs. Research-derived information used in Extension programs comes from The Ohio State University, the Ohio Agricultural Research and Development Center and the United States Department of Agriculture.

Educational assistance based on information from these sources is made available to people through a professional Extension staff of county and area Extension agents and state Extension specialists. These staff members work closely with citizens who are members of the county, area and state Extension advisory committees. They also work with local, state and federal organizations, agencies and other groups in identifying major problems and determining objectives to achieve solutions to the problems.

The Ohio Cooperative Extension Service efforts in Livestock Waste Management involve assembling facts and scientific research from various sources. This information is provided for farmers, industry, organizations, governmental agencies and all concerned citizens. Bringing the concerned and involved people in contact with factual information is the objective of the Extension Service.

OHIO DEPARTMENT OF NATURAL RESOURCES

The Division of Soil and Water Districts, Ohio Department of Natural Resources, coordinates the activities of the local Soil and Water Conservation Districts to encourage livestock owners and operators to apply the required levels of operation and management for pollution abatement. Chapter 1515 of the Ohio Revised Code gives the Division regulatory authority and responsibility for controlling water pollution from concentrated animal feeding operations.

Soil and Water Conservation Districts: Each District, through its agreements with the Cooperative Extension Service, the U.S. Soil Conservation Service, the Division of Soil and Water Districts and other pertinent agencies, will provide information, technical assistance and cost-share assistance to owners of animal feeding operations regarding animal waste pollution abatement. There is a district office located in each county.

OHIO ENVIRONMENTAL PROTECTION AGENCY

The Ohio Environmental Protection Agency provides for a site inspection of the proposed animal waste facility when applicable (see section on Animal Waste Pollution Abatement Program). Inquiries regarding applications and available assistance should be made to the District Office.

Central District—361 E. Broad Street
Columbus, Ohio 43215
(614) 466-6450

Northeast District—2110 E. Aurora Road
Twinsburg, Ohio 44087
(216) 425-9171

Northwest District—1035 Devlac Grove Road
Bowling Green, Ohio 43402
(419) 352-8461

Southeast District—Route 3, Box 353
Logan, Ohio 43138
(614) 385-8501

Southwest District—40 S. Main Street
Dayton, Ohio 45402
(513) 461-4670

SOIL CONSERVATION SERVICE

The Soil Conservation Service, an agency of the U.S. Department of Agriculture, provides technical assistance to landusers for planning, design and construction of agricultural waste management systems.

The systems are planned to contain solid and liquid wastes and manage storm runoff from areas with heavy concentrations of animals. Storage and disposition of the waste material is planned in a manner that does not degrade such resources as air, soil and water.

The Soil Conservation Service also assists landowners by providing plans and other data needed to obtain approval for such projects.

Information regarding agricultural waste management systems and technical assistance is available upon request to local Soil and Water Conservation District offices.

PUBLICATIONS

Two sources of publications are available through the Ohio Cooperative Extension Service: (1) articles prepared and distributed by the Ohio Cooperative Extension Service and (2) those by the Midwest Plan Service.

Agricultural Engineering Extension publications (AEX Series) are available through the County Extension offices. Subject material covers building and structures, waste management, soil and water, power and machinery, safety and others. Most of these publications are free when a single copy is requested.

The Midwest Plan Service is a cooperative regional activity of the Land Grant College of the North Central United States. The objective of the Plan Service is to prepare and distribute up-to-date plans and related materials for rural housing, farm service buildings and other related equipment. One area of activity for the plan service is livestock waste management. A list of the waste handling publications, plans and technical data sheets available to the producer from the Midwest Plan Service are listed below. The price of each item is also listed.

MWPS Technical Resource Sheets	
TR-3 Concrete Manure Tank Design	$1.00
TR-4 Welded Wire in Concrete Manure Tanks	.50
Agricultural Engineers' Digests	
AED-17 Siphon Flush Tank	$ .50
AED-18 Selecting Dairy Manure Handling Systems	.50
AED-19 Slip Resistant Concrete Floors	.50
AED-22 Tilt-up Concrete Construction	1.00
AED-23 Outside Liquid Manure Storage	1.00
Handbooks	
MWPS-18 Livestock Waste Facilities Handbook	$2.50
Plans	
74303 Liquid Manure Tanks	$1.00

In addition to these publications, which deal exclusively with waste management, the following handbooks include sections on waste management.

MWPS-2 Farmstead Planning Handbook	$2.50
MWPS-3 Sheep Handbook	2.50
MWPS-6 Beef Handbook	2.50
MWPS-7 Dairy Handbook	3.00
MWPS-8 Swine Handbook	2.50

Numerous plans are available for swine, dairy and beef production facilities. These plans include provisions for waste handling and storage. A free catalog is available upon request.

These plans and publications may be obtained by writing to: Agricultural Engineering Extension, 2073 Neil Avenue, The Ohio State University, Columbus, Ohio 43210. Please make checks payable to The Cooperative Extension Service and enclose with order.